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USE OF FACTORY STATISTICS FOR THE INVESTIGATION OF INDUSTRIAL FATIGUE

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USE OF FACTORY STATISTICS IN THE INVESTIGATION OF INDUSTRIAL FATIGUE

A Manual for Field Research

BY

PHILIP SARGANT FLORENCE, M. A. (Cambridge) Ph.D. (Columbia)

Garth Fellow

Scientific Assistant, United States Public Health Service

New York

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To

MY MOTHER

MARY SARGANT FLORENCE

WHOSE EARLY CONCERN AND CONSTANT INTEREST IN HER CHILDREN'S GROWTH OF MIND LAID THE FOUNDATION FOR THIS ESSAY

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INTRODUCTION

THE study of industrial fatigue has now reached the point where a summary can be given of the methods that have been most usefully employed and where fresh lines of investigation can be laid down to link up the results of current researches. The experience picked up painfully and wastefully by means of trial and error can now be taught as a body, logically and succinctly.

Individual experiments such as that of Abbé at the Zeiss Optical Works in Jena in 1900 have been succeeded by a systematic search for records on the part of an organized group of investigators. Terms have been standardized; ideas and experiences in the solution of difficulties have been pooled; methods that appeared theoretically sound have been rejected or modified in practice; in fact a tradition has grown up to which each successive investigator has added his share.

The position of the human element in the factory and the whole surrounding industrial system is variegated, involved, and full of interacting factors. Statistical methods, however, can be applied fruitfully only where the ground is uniform and where what is cause and what is effect can be at least roughly guessed. The work of pioneers seems therefore necessary to prepare the soil of industry for the statistician; and it is in this rôle that the present work may be accepted. It is an attempt to reduce some classes of industrial facts to a measurable form and to warn the statistician proper of the difficulties involved in the measurement itself.

Every factory presents its own peculiar situation and the rules embodied in this work must not bind statistical investigators dogmatically. Every separate situation requires some preliminary surveying in order to secure a proper orientation, yet in the actual conduct of the separate inquiries similar stages can be distinguished, and by division of labor, special types of investigators can all co-operate in the common task.

First is required a general visit to the factory where hygienic arrangements and the conditions of work can be noted cursorily and inquiry can be made as to the sources of record available either in the factory's books or through specially instituted observations. At this stage a visiting committee is of the greatest service.

Secondly, the ground must be prepared for the statistical investigation. The scope of the inquiry must be designed to yield accurate and significant results. The observations and tests to be made must be carefully selected and circumspection exercised to recognize disturbing factors. Here is required a supervisor experienced in detecting situations likely to produce fatigue and familiar with industrial conditions generally.

The facts can then, in the third stage, be collected. Either records are extracted from the books of the firm or operations are directly observed and recorded in the factory itself. This constitutes the actual field observation.

At the fourth stage comes the process of generalizing the individual records according to their value as evidence by mathematical calculations of averages, deviations and coefficients of correlation, etc. Part of this work should be done in the field, in case further information about factory conditions is found necessary, but as soon as a specimen result has been completed the work may continue wherever convenient.

The next stage is that of explaining the generalized results on some hypothesis of cause and effect. This often proceeds concurrently with stage four but requires again the presence of a supervisor familiar with the industrial situation.

Finally comes the written presentation of the investigation in the form of a report, which must be clear in all respects. The procedure should be definitely described under headings such as (1) Source of Records, (2) Methods of Study, (3) Results, (4) Explanation of Results, (5) Recommendations. All circumstances of importance should be made known, such as the exact nature of the observations—the number of individuals studied and the range of place and time; the actual hours of labor at the factory and the type of work engaged in; the incentives to work and the conditions surrounding the work. A full list of such circumstances is given on page 26.

It is the special purpose of this work to initiate American investigators into these methods of research. In America, which by 1914 was leading the way in studying fatigue through the official tabulation of accidents and output, interest has since concentrated on laboratory experiments such as those of Dr. F. S. Lee. In England the frantic increase of factory hours in the munitions industry consequent upon the outbreak of war called the attention of the Government very definitely to the existence of human limits in actual production in the factory.

The general scheme of investigation was outlined by the writer in the Report of the Committee on Fatigue from the Economic Standpoint presented to the British Association for the Advancement of Science, meeting at Manchester in September, 1915. Two-thirds of the material of this report was drawn from American sources. A few weeks later

Professor Stanley Kent reported to the British Home Office on an "Investigation of Industrial Fatigue by Physiological Methods." Meanwhile a committee was appointed by the British "Minister of Munitions with the concurrence of the Home Secretary to consider and advise on questions of industrial fatigue, hours of labor and other matters affecting the personal health and physical efficiency of workers in munition factories and workshops." The chairman was Sir George Newman M.D. and many other medical authorities and government factory inspectors—men and women—were placed on the committee. Twenty memoranda and one Interim report have already marked the activities of this body.[1] All these publications are reprinted in the U. S. Bureau of Labor Statistics Bulletins 221, 223 and 230.

Suffering now from their hasty demand for increased hours, employers in England have welcomed the investigators [2] and even approached them for advice. The writer himself has, at the request of manufacturers, recommended Saturday half-holidays, pauses in the middle of the morning and the afternoon, the cessation of night work and the general decrease in working hours. He was able to suggest many technical improvements in the keeping of the manufacturers' own records and through these records was able to point to such hindrances as limitation of production and misunderstanding of the wage systems on the part of employees [3] and even to maladjustment in the setting of piece rates on the part of the management.[4]

[1] *Memoranda* nos. 7 and 12 were reprinted in the *Interim Report.*

[2] *British Health of Munition Workers Committee Memorandum,* no. 7, p. 12 footnote. *Bulletin of U. S. Bureau of Labor Statistics,* no. 221, p. 63.

[3] *British Health of Munition Workers Committee Interim Report,* pp. 71, 72, 73. *Bulletin,* no. 230, p. 100.

[4] *Ibid.,* p. 75. *Bulletin,* no. 230, p. 105.

The detailed explanation of methods embodied in this handbook will, it is hoped, lead employers, employees and the community at large to appreciate the disinterestedness of aim in the investigation of fatigue, the validity of results and the importance of conclusions and recommendations.

The conclusions that have been reached up to the present by authorities in England, Germany, America and other progressive countries, the writer hopes to set forth in a forthcoming volume on "Industrial Fatigue." These conclusions affect all classes; they involve national wealth and national vitality, the sum of human gains and human costs. Employers, labor leaders and governmental authorities cannot afford to neglect their lesson. "The facts are our masters."

Yet the crying need is for more and more investigation; and this present handbook is dedicated to the hope that all who can, will join in research along the lines suggested, to strengthen the foundations and to broaden the range of our knowledge of human fatigue and of its incidence in industry.

The author wishes to express his thanks to all those who have helped him toward a true appreciation of the importance of industrial fatigue, and to all those who are co-operating with him in the work of research.

He remembers with gratitude the zest for truth in all economic speculation among his Cambridge associates, and the guidance and support received from Walter T. Layton, Fellow of Caius College. Among the Committee on Fatigue from the Economic Standpoint of the British Association for the Advancement of Science, the author is particularly indebted to Miss B. L. Hutchins, Miss A. M. Anderson, Principal Lady Inspector of Factories, Professor Muirhead, Mr. Edward Cadbury and Mr. C. K. Ogden, upon whose

erudition and common sense the author has often relied. Among the British Health of Munition Workers Committee and their investigators, the author is indebted to Dr. Edgar Collis, Chief Medical Inspector of Factories, Captain M. Greenwood, R. A. M. C., and Dr. Morley Fletcher, Secretary of the Medical Research Committee created under the National Health Insurance Act, grants from which enabled the author to undertake much of his later work in England.

In America the author has met equally generous help, and he wishes to acknowledge his special obligation to Professor Frederic S. Lee for practical encouragement and sympathetic criticism. The author has been greatly privileged also in his association with Miss Josephine Goldmark, Professor R. E. Chaddock of Columbia University, Professor A. H. Ryan of Tufts Medical College, and Assistant Surgeon General J. W. Schereschewsky of the United States Public Health Service.

PART I

ELEMENTS

CHAPTER I

Fatigue

Fatigue may be defined for our purposes as a diminution of working capacity, often accompanied by feelings of weariness, caused in the human organism by the length or intensity of some activity.

THE HUMAN ORGANISM

Though the application of physiological definition is impracticable in the present state of our knowledge, yet it is important, for the benefit of investigators without physiological training, to emphasize the fact that the fatigue they are seeking is something very definite and physical and by no means merely imaginative.

The actual *modus operandi* within the human organism, whereby length and intensity of activity causes diminished capacity, and rest causes an increased capacity, is described very vividly in the British Health of Munition Workers Memorandum No. 7.

In the animal body the performance of work depends on the activities of parts which are best considered under three groups —first, the complex nervous mechanism of the brain and spinal cord, which are concerned in the initiation and distribution of impulses to action; second, the nerves, which conduct the impulses to muscles; and third, the muscles themselves, which by contracting finally perform external work.

Fatigue has been separately studied in all these parts. In its essential features the fatigue of all alike has been found, when it occurs, to depend not upon the simple using up—"exhaustion"—of the substances supplying the chemical energy which is liberated during work, but upon the accumulation within the living elements of the products of the chemical changes involved. Fatigue of the animal machine, that is to say, is not to be compared with the failure of fuel as in a steam-engine, or with the running-down of a clock weight, but rather with the clogging of the wheels in some mechanism by dirt.

The chemical products of activity in the nervous and muscular elements are removed by the blood, in part directly by irrigation, and in part indirectly through chemical changes in the tissue itself induced by constituents of the blood. Rest after activity is not a passive state, therefore, but is itself an active process, or a series of active processes, leading to a restoration of the normal capacity for work.

FEELINGS OF WEARINESS

The popular notion of fatigue is certainly that of a feeling or sensation of tiredness, sleepiness, or weariness. Yet such feelings are a very uncertain measure of a diminution in working capacity.

As Dr. Rivers has stated "A distinction must be made between the sense of fatigue—the sensations which supervene during the performance of work, and the lowered capacity for work executed. These conditions, which may be spoken of as subjective and objective fatigue respectively, do not always run parallel courses. In the performance of mental work, especially, decided sensations of fatigue may be experienced when the objective record shows that increasing and not decreasing amounts of work are being done; and there may be complete absence of any sensations of fatigue when the objective record shows that the work is falling off in quantity, or quality, or in both."

This insistence on the distinction between subjective and objective fatigue, however, does not imply that the one has no influence on the other. As Max Weber [1] points out, "This psychically conditioned fatigue is by no means without its influence on working capacity . . . and in the long run it can undoubtedly cause an unfavorable general disposition which will ultimately find a physical expression." For instance, "a man's driving power ('Antrieb') is apparently influenced unfavorably by the tedium of his work and (at the start) by the consciousness of a long day's work before him."

THE DIMINUTION OF WORKING CAPACITY

The tendency to fatigue is by no means the only psycho-physical process that affects the working capacity during working activity; but it is the only such process which ultimately affects a diminution of working capacity.

For the full discussion of all the psycho-physical processes which, together with fatigue, influence the working capacity during activity, reference must be made again to Max Weber's "Psychophysics of Industrial Work." [1] Of these processes, the most important are "practice," "spurt" and "incitement."

[1] "Zur Psychophysik der industriellen Arbeit," in the *Archiv für Sozialwissenschaft und Sozialpolitik.*

Articles: I vol. 27 (1908), pp. 730 ff.
II and III vol. 28 (1909), pp. 219-277 and pp. 719-761.
IV vol. 29 (1909), pp. 513-542.

These articles by Weber fall into two parts; the first part, consisting of the first article and the beginning of the second, is an attempt to view Kraepelin's psychological study of fatigue from the economic standpoint, and has been translated in full by Mr. C. K. Ogden, for the Committee on Fatigue of the British Association, but not yet published.

In the second part, Weber has, to quote his own words, "given an illustration of how factory statistics are to be handled", so as to "throw further light on the conclusions of Kraepelin."

In Practice Weber sees the process which leaves "the conscious will and the power of attention" free for application elsewhere, and which "probably means a quite direct saving of energy through the removal of pressure from the central nervous system." Its manifestation is the "increase of facility, rapidity, certainty, and regularity of a particular action or operation through its frequent repetition." The result on working capacity may be expected to be that "at the beginning the increase in practice outweighs the early fatigue, so that the output curve as a whole moves upward," but "as the work continues the fatigue begins more and more to outweigh the increase of practice in its effect on the output."

By Incitement (*Anregung*) Weber means a "psychomotor state" which "arises in a purely mechanical manner from the work itself, and without the active intervention of the will," and he supposes that "it usually makes itself felt very shortly after work has begun, and that after fairly short intervals, sometimes of about a quarter of an hour, it suddenly vanishes away." As Dr. Myers points out, the result of the loss of incitement is familiar enough when we return to a task from which we have been called away, even for a few minutes.

By Spurt (*Willensantrieb*) Weber means "an impulse arising under special conditions and carrying sudden outbursts of energy. . . . Its typical effect is seen in short, sudden rises in the curve at the beginning of work, after disturbances and almost equally regularly at the conclusion." It may be caused by the desire to earn more or to finish off well, or even by a smitten conscience, or by the desire to come up to a certain standard.

To these three psycho-physical processes a fourth might be added which the accident statistics collected have shown to be important. Weber came very near to distinguishing

this tendency, though negatively, when he wrote that "a man's driving power is apparently also influenced unfavourably by the tedium of his work and (at the start) by the consciousness *of a long day's work before him.*" I refer to the excitement that accompanies the anticipation of a rest, a change and food near at hand, with possibly also the satisfaction derived from work accomplished, the same frame of mind that makes schoolboys at end of term exclaim with glee:

> "In two weeks where shall I be?
> Not in this acadamee . . . "

This factor, like incitement, is not a manifestation of the will, but contrary to incitement it is due not to something "in" the work, but something "outside" it. Indeed, as my colleague Mr. C. K. Ogden has suggested, "*ex*citement" seems a "peculiarly appropriate name for this feeling, though if it is held too broad a term "Anticipation" or "Relief" might be used, or "Anticipatory Excitement."

Industrial activity, therefore, may increase working capacity through the influence of practice, increased interest, spurting, and anticipatory excitement, but fatigue may be regarded as a constant tendency in the opposite direction. It is not so much the sum of the results of activity, as the British Health of Munition Workers Committee defines it,[1] but rather the ultimately predominating result. At first fatigue may predominate to the extent only of lowering efficiency, i. e., the actual product of working capacity, but in its later stages health itself may be affected, i. e., the actual seat of working capacity may be attacked. Therefore, both fall in efficiency and loss of health will hereinafter be included in the conception of diminution of working capacity.

[1] *Memorandum*, no. 7, p. 3. *Bulletin of U. S. Bureau of Labor Statistics*, no. 221, p. 47.

CHAPTER II

Industry

Industrial fatigue is a diminution of working capacity caused by the length or intensity of some activity at a "gainful occupation." Under the industrial system of today such occupation is usually carried on within a factory where machines have, to a large extent, taken the place of human strength and human dexterity. Moreover, in the parlance gradually being adopted from the social worker, the adjective "industrial" is applied only where the gain is comparatively a small one. Industrial life insurance, for instance, refers only to the lives of the *poorer* classes. Industrial fatigue may be defined roughly, therefore, as the fatigue occurring mostly in the factory among those gaining a bare living by their work.

For the benefit of such investigators as are not already acquainted with industrial conditions, it may be well to enlarge upon these implications of the adjective "industrial". Most medical men and all too many theoretical economists and statisticians are woefully ignorant of the conditions under which the greater number of our occupied population work and live. A brief review of industrial conditions from the standpoint of fatigue may save otherwise excellently equipped investigators from the grossest miscalculations.

THE WAGE SYSTEM

That an occupation is carried on *for the sake of gain*, whether for wages or profit, implies a steady "incentive"

towards just that prolonged and intense activity which is liable to produce fatigue.

Where the gain is low and perhaps only just sufficient to provide a living for the worker and his family, the incentive is obviously all the more intense, and it will induce every member of the family to go out to work—husband, wife, children, grandparents—without distinction of age, sex or training.

In addition to this, the lower the gain the worker secures, the less adequate will be his food, housing and recreation and the less choice will he have in its selection. Conditions will be imposed upon him by circumstance rather than chosen by himself to satisfy his taste and needs. The industrial worker cannot take a vacation just " when he feels like it," without suffering absolute privation.

HOURS OF LABOR

That an occupation is carried on within a factory where hundreds of other individuals are employed and similarly occupied, implies a certain stereotyping of working conditions, and particularly a rigidity in the hours of labor.

In spite of legal enactment, trade unions, and the initiative of benevolent employers, the average " employed " factory hand still works 5½ or 6 days a week and 8 to 10 hours a day, and even longer in a few continuous industries like iron and steel.

Often the exact total hours of work *per week* are standardized and ascertainable in government publications. A rough estimate, made in 1906,[1] gave as the typical week's work 53-55 hours in England and 60 hours in Germany, while the American working week, though most variable, also averaged 60.

[1] See Arthur Shadwell, *Industrial Efficiency*, vol. ii, Longmans, Green and Co.

The distribution of the hours into spells of continuous work differs considerably in different countries. In America a five-hour spell, then dinner, then four or five hours more is the rule; on the continent of Europe short breaks often occur in the middle of the morning and afternoon; while in England the day generally consists of two hours work, half-hour breakfast, four hours work, one hour dinner, four hours work, tea. This general standardization applies also outside the factory to the building trades; and to agriculture, lumbering, and mining as regards day and week, but not as regards spell, for here breaks in the work are taken somewhat irregularly according to opportunity and inclination.

Any temporary departure from the standard number of hours in the direction of reducing them is known usually as working short time and in the direction of lengthening them as working over-time. In England, for instance, the term over-time refers to those hours worked beyond the trade-union standard, though occasionally the term is applied only to hours worked beyond the legal, factory-law maximum.

Where it is necessary to run a factory plant continuously without meal-intervals, day and night, Sundays and week days, there the human force will be obliged to work in "shifts". One shift of workers will relieve the other like the watches on board ship. To cover the whole twenty-four hours there are usually either three shifts working eight hours each or two shifts working twelve hours each. To avoid one shift being continuously on night work the shifts are usually "rotated" or "inverted" every week, fortnight or month; the men on nightshift then come on dayshift and *vice versa;* where three shifts exist the workers on shift A then go on shift B, B on C and C on A.

The necessity for such continuous work usually arises

from the technical requirements of the industry. In iron-smelting and steel-making and in various processes of the chemical, glass, cement and sugar-refining industries operations would fail if interrupted at all, and constant vigilance is required over the equipment and the material. The necessity may also arise, as in telephone exchanges, from the demands of the market. The demand in 1914 for munitions of war turned the whole of the English engineering trade into a continuous industry for men and women alike.

THE CONFORMATION OF WORKING LIFE

Chronologically then, working life in general may be summed up as a series of recurrent cycles embracing alternating periods or elements of rest and work, the one balancing the other. This alternation of activity and relaxation is so essential to the continuance of existence that the Health of Munition Workers Committee have been moved to speak of it as a rhythm and to compare it to the action of the heart. "For every acting element a given rhythm of activity will allow exact recovery after each act, and will maintain the balance between action and repair throughout a long series. The heart, for instance, in alternating contraction and relaxation may continue to beat incessantly through the life of a man without any accumulated fatigue for seventy years or more."

The element of rest is in industry proper much shorter than in the "professions" or even among business men. Only occasionally, as in the Lancashire cotton industry, does the year contain a vacation or holiday. However, the industrial week usually contains the Sunday rest prescribed in the Scriptures, and often this is extended, as in the English week-end, to include Saturday afternoons. In each cycle of twenty-four hours the worker secures an element of sleep—during the day if he is working nightshifts; at night

if he is working in the daytime. Within the working day of ten hours or so, the "conformation" of the day is so far standardized that it is highly desirable to standardize our terminology correspondingly. At present every factory district, even every single factory, has different words for the same custom and even the same word for different customs.

Owing mainly to the necessity of taking meals regularly the work of the whole day is usually split up, as we have seen, by meal-*intervals* into several turns or *spells* of continuous work. Even these spells, however, are sometimes interrupted by short *breaks* or *recess-periods* when the workers are allowed a glass of milk and a chat.

While, however, spells, intervals and breaks are set at certain times by the clock, the work itself falls into certain other divisions in accordance not with meteorological calculations, but with the very nature of the work. Certain "operations" have to be performed before a product is complete and certain "motions" (manipulations, postures, strains) have to be performed or endured within the given operation. Here again, however, there is usually an alternation of work and rest. Parts of the operations of necessity often consist not in motions but in "pauses"—waiting for the material to set or for the machine to finish, *etc., etc.* Between operations, again, *pauses* may be introduced artificially by the management [1] or by the worker's own tradition.

It is worth noting that by increased technical efficiency in preparing the materials and by increased division of labor, industry has largely succeeded in eliminating the natural pause; the worker no longer need wait for "things to happen." But industry has not introduced a corresponding proportion of artificial pauses, breaks or intervals. It is a

[1] *Cf.* Taylor, *Principles of Scientific Management*, pp. 41-59, 92. Gilbreth, *Fatigue Study*, pp. 127-131.

task for the investigator to gauge how far the working capacity has lost by this failure to compensate loss in relaxation.

THE COMPLEX OF FACTORS

The industrial situation thus presents a complex of factors, all of great importance in the production of fatigue. Though, according to definition, length and intensity of activity always remain the main or active factors in the causation of fatigue, yet the occurrence of this causation may be hastened or retarded according to the conditions surrounding the activity (standard of wages and factory hygiene, *etc.*) and according to the nature of the work and type of worker, and so on.

It is imperative, therefore, for the investigator to set clearly before himself all the factors in industry that may predispose the human organism to fatigue—partly that he may be sure that he is not omitting from his inquiry any clue to, or possible cause of, a diminution of working capacity, partly that he may secure evidence as to the comparative importance in fatigue-production of all these different industrial conditions.

Accordingly, many schedules have been drawn up by individuals and by governmental departments in various countries, of all the industrial conditions that influence or might be thought possibly to influence working capacity, and the writer ventures to present below a table of conditions analytically arranged, and as discriminating as his own experience and a comparison of all previous tables can make it. This table has been found of great practical use in the field. Incidentally it may be said that each of these conditions has an importance of its own and such a schedule may serve as a questionnaire or blank form to be filled in by social investigators of various types.

SCHEDULE OF INDUSTRIAL CONDITIONS

I. Length and intensity of activity.

II. Factory conditions: Hygiene and Employment Management.

A. *Physical: Time and Place of Work.*

1. Air: Temperature and Humidity; Ventilation and Room-space; Dust and Fumes, Exhaust Systems; Smell.
2. Light: Volume, Concentration, Glare.
3. Noise: Volume, Irregularity, Vibration.
4. Accident Hazards: Safety Devices; First Aid.
5. Feeding: Sale of Food; Equipment; Service.
6. Sanitation: Drinking Water; Rest Rooms; Baths.

B. *Social and Economic.*

1. Flow of Work. Depressions and Rush Orders. Routing.
2. Creation of Staff. Appointment and Dismissal. Permanency of tenure. Unemployment. Instruction and Supervision.
3. Maintenance of Production.
   Incentives: Natural interest in work. Scale, method and assurance of wage payment.
   Discipline.

III. Nature of the Work.

IV. Type of workers.

A. *Sex, Age, Race.*

B. *Experience.* Date of entering industry and factory. Former occupations.

C. *Habits and Home Conditions.*

1. The Amount and Use of Earnings. Thrift.
   Food: Diet and Time of Meals.
   Stimulants: Alcohol and Tobacco.
   Sleep and Recreation: House Accommodation and Hygiene.
   Support of Dependents.
2. Method and Length of Transit from Home to Work.
3. Duties outside Factory (Housework of Women, etc.)
4. Sexual and Family Relations.

D. *Point of View* ("Animus"). Trade-Unionism, Patriotism. Economic Self-Interest, Herd-Instinct *etc.*, General Intelligence

CHAPTER III

INVESTIGATION

FATIGUE was defined as a diminution of working capacity caused by the length or intensity of some activity. The notion of fatigue implies in itself, therefore, a coupling of two occurrences in the relation of cause and effect. Here lies a danger. The use of the word fatigue by definition implies the existence of the very process that we are trying to demonstrate. The word, in the earlier stages of argument, must be dropped altogether; and to avoid begging the question in the final demonstration two distinct steps are called for: first, to show and measure the fact of a definite diminution of working capacity, and, secondly, to associate this diminution with the fact of a definite increase in the length or intensity of activity.

The diminution of working capacity has been measured either in terms of records of the actual every-day events of life or else in terms of artificial tests of the individual's working capacity. These are the "data" with which to measure.

The association of degrees of activity with this diminution may take place either "experimentally" under the standard conditions of the laboratory by creating and regulating artificially the degree of activity to be displayed, as when the "subject" is made to walk for a given number of hours along a band moving in the direction opposite to him, or else the association may take place "statistically" under the ordinary complex conditions of life by observing sufficient cases of ordinary complex activity.

Fatigue may therefore be investigated through three different routes:

1. Observations through ordinary records of working capacity associated with the ordinary activities of life, *e. g.* by counting the number of accidents occurring as work proceeds in the factory.
2. Observations through artificial tests of working capacity associated with the ordinary activities of life, *e. g.* by testing the visual acuity of men before and after their day's work in the factory.
3. Experiments in the laboratory: artificial tests of working capacity associated with artificially produced activities. In many cases the activity may be made to test itself. Thus Mosso's ergograph both evokes activity and measures the associated capacity.

Industrial fatigue, however, would only be established by seeking the causal association in the actual length or intensity of activity in the factory or other place of gainful occupation. For this purpose artificial tests (Route 2) would only be useful when taken while activity proceeds in the factory or just before and just after such activity, and laboratory experiments (Route 3) would be useful directly only in so far as the conditions of industry are reproduced. Both tests and experiments may indirectly, however, throw much useful light on special phases.

LABORATORY EXPERIMENT

The applicability of such experiments to industrial fatigue was discussed very fully in the second report (issued in 1916) by the Committee on Fatigue from the Economic Standpoint of the British Association for the Advancement of Science.

While it was urged that "laboratory work is able to study certain factors in isolation in a manner which the compli-

cated conditions of factory life render impossible, . . . the value for industrial purposes of experimental work which does not reproduce the actual processes and machinery of the factory itself" was very much questioned.

On the one hand, Muensterberg has pointed out that unless concrete situations are reproduced *in toto* we can never be sure that the omission is not an essential factor. He illustrates the argument by the contention that a reduced copy of an external apparatus may arouse ideas, feelings, and volitions which have little in common with the processes of actual life. The man to be tested for any industrial achievement would have to think himself into the miniature situation, and especially uneducated persons are often very unsuccessful in such efforts. This can clearly be seen from the experiences before naval courts, where it is usual to demonstrate collisions of ships by small ship models on the table in the court-room. Experience has frequently shown that helmsmen, who have found their course all life long among real ships in the harbour and on the sea, become entirely confused when they are to demonstrate by the models the relative positions of the ships.

On the other hand, we have the very natural objection that any abstraction from the actual conditions must, to some extent, vitiate the applicability of the results obtained.

One of the most important general differences between laboratory experiments and the normal conditions of the factory is to be found in the difficulty of ensuring any degree of *natural affective behaviour* in any kind of experiments suitable for laboratory investigation. Thus the very important factor constituted by the subject's every-day interests is not likely to show in the laboratory even where instructions are given to "behave naturally". The chief "interest" which the subject is likely to feel is a certain curiosity as to the results of the experiment itself—a state of mind which has no precise parallel in the industrial field.

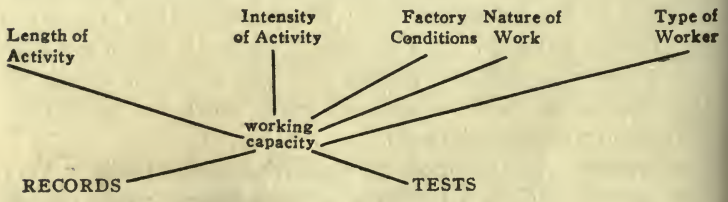
Moreover, the conditions of experimentation imply a very high average degree of tension, and of concentration on the

operation or reaction of the moment, with no reference to the affective side of the personality taken as a whole. In the factory, on the other hand, the worker spends the greater part of his life; on his work the continuation of his existence largely depends. Boredom or joy in work may here exercise a peculiar influence on output—not less than economic considerations based on desire of the most far-reaching character.

Hence in experimental work the immediate conditions of attention are chiefly of an objective nature, such as the intensity, extent, and duration of the stimulus; in the factory, attention is more frequently determined by the mental relation of the worker to his work, by his needs and desires, by his moods and by his "interests".

OBSERVATION OF "ACTUALITIES"

The situation confronting the investigator of industrial fatigue in the actual place of work may perhaps be simplified by means of a crude diagrammatic representation. In the foreground we may picture well ascertained records of ordinary events or tests of ordinary activity. As looming in the background may be imagined the equally well ascertainable data of industrial conditions: the length and intensity of activity in the factory, the nature of the work, the type of worker, factory conditions and organization, depending on fundamental natural and economic conditions, such as the weather, demand and supply, *etc., etc.* In the midst of the whole perspective is situated the human working capacity influenced by the background conditions and producing the foreground results.



Fatigue, and similarly the opposing tendencies of spurt, practice and incitement, can be only such influences passing from length and intensity of activity and the other factors in the background to data in the foreground, *as pass through the working capacity,* i. e., where the " mechanism " of the influence centers in the human body. But the background conditions might and do effect foreground results without this intermediate stage. For instance, dry weather may cause the record of spinning output to fall, or artificial light will increase the record of accidents, or labor-union restrictions may limit the individual's output as activity proceeds; but all these couples of causes and effects cannot be called fatigue because they do not pass through working capacity.

The scheme of an investigation into Industrial Fatigue may be set forth in the terms of the above diagram as an attempt to trace back from the data of tests and records in the foreground, through the working capacity in the middle, to the industrial conditions in the background, primarily to that of length and intensity of activity.

THE STATISTICAL METHOD

As the title of this work implies, the discussion will be confined to the use of factory statistics, *i. e.,* the actual records of ordinary work performed in the ordinary places of work; the artificial tests of fatigue that are in use have been described thoroughly elsewhere.[1] The events that can be observed and recorded in factories and that can be used to throw light on fatigue may be itemized as follows (each item will be awarded a separate chapter in Part II) :

A. The Output Rate per given period of time.
Chapter IV

[1] The reader may consult Professor Whipple's *Manual of Mental and Physical Tests* published by Warwick and York, Baltimore, Md.

B. The Consumption of Mechanical Power at any given moment. Chapter V

C. The Rate of Accidents per given period of time. Chapter VI

D. The Proportion of Spoiled Work to Output. Chapter VII

E. The Proportion of Sickness and Unrest among the Industrial Population. Chapter VIII

We have said above that the purpose of investigation in general was to trace back from the data of records through working capacity to certain conditions in the industrial background. In this sentence, it will be noticed, there is no object, no accusative. What is it that we are to trace? The answer is that we are trying by means of factory records to measure *variations* in the degree or amount of working capacity, and are then attempting to trace these variations in degree of working capacity back to certain variations in degree of intensity and length of activity and other industrial conditions. Furthermore, we must attempt to present both these variations as " representative " or " typical " as possible by calculating the averages and the reliability of averages. Our final objective is to discover some correspondence, if any, between representative variations in degree of working capacity on the one hand, and, on the other, associated representative variations in degree of intensity or length of activity or in industrial conditions generally. *To demonstrate fatigue we must correlate the associated variations.*

The complete investigation, logically analyzed, therefore, falls into the following sections, to each of which is devoted a separate part of the present work:

I. Measurement of Variations in Working Capacity. Part II

II. Measurement of Variations in Length and Intensity of Activity and in Industrial Conditions.
Part III

III. Correlation of Representative Variations of Working Capacity with associated Representative Variations of Activity and Industrial Conditions.
Parts IV and V

This schedule is the logical analysis, but the exigencies of the industrial situation have prevented the text of this work being moulded in quite the purely logical form. The modifications that are made necessary are as follows:

1. The usefulness of the measurement of activity depends on the actual opportunity offered by industry of finding variations in activity associated with measurable variations in working capacity. Hence while the measurement of working capacity is treated independently and at some length in Part II, the full discussion of the measurement of activity is removed from Part III and taken up jointly with the discussion of the correlation of associated activity and capacity, in Part IV. Similarly the usefulness of the measurement of industrial conditions depends on the actual opportunity of finding them associated with variations in working capacity, and the full discussion of the matter is postponed to Part V, dealing with their correlation when associated.

2. The measurement of working capacity and the measurement of length and intensity of activity and of industrial conditions generally cannot be treated along the same lines. Variations in working capacity occur spontaneously and involuntarily. Variations in activity and conditions are deliberately regulated either by the workers themselves or their employers. Under the modern system the degree of activity and the character of working conditions are deter-

mined predominantly by those authorities who manage the factory. Who shall work, and how long and how hard, and on what jobs and under what conditions is determined mainly over the heads of the workers themselves. Hence Part III, deprived of the main discussion on the measurement of activity and conditions, is devoted to a discussion of the scope and limitations of the deliberate determination of working conditions, and an exposition of some of the problems confronting those in whose power is this determination—problems in which the study of fatigue may give light and leading.

3. The industrial conditions likely to retard or predispose the causation of fatigue are considered separately in Part V, for the reason that they play a double rôle in the situation. They are, on the one hand, associated with activity in affecting working capacity; on the other hand they often introduce elements that cloud the issue. The factor of learning by experience, for instance, results in a *greater* working capacity, the longer and the more intense the activity. Hence the object of the investigator is not merely to associate these factors in the causation of fatigue, but also to dissociate such foreign elements as these factors introduce. This task is different and peculiar for each individual factor, and they are considered one by one in separate chapters.

PART II

THE MEASUREMENT OF WORKING CAPACITY

THE first stage in the investigation of industrial fatigue is to connect the data derived from records with working capacity. Data must be chosen to *measure* working capacity accurately. For this, three conditions are necessary:

1. Data must for statistical purposes either be units or be divisible into units of the same uniform quality, and thus be capable of quantitative enumeration.[1]

2. Data must be quite sensitively indicative or "expressive" of working capacity. Variations in data must be acceptable as expressing all variations in the working capacity. The events of a modern factory are usually the results of a combination of mechanical and human forces. The less the "human element" enters into the combination, however, the less fully and easily can human working capacity be measured. The "results" are "masked" and the data may be said to be inexpressive or reticent. For instance, if the speed of a machine operation is to a large extent "set" at a constant rate by mechanical causes, variation in human working capacity will be reflected but reticently by variations in output.

Working capacity is not so much a single entity as a

[1] The exact degree of uniformity required depends on the subject of investigation. Accidents need not be uniform in severity since any accident, however slight, is a symptom of diminished capacity. Measures of working capacity need be uniform only to the extent that each unit should express the same degree of working capacity.

combination of inherent faculties and aptitudes. Working capacity may be looked upon as composed of two dimensions: the power to work rapidly and produce good quantity, and the power to work proficiently and produce good quality. The power of rapidity is difficult to analyze further; it is indistinguishably bound up with nervous structure and the individual's temperament. The power of "proficiency" can be viewed as a bundle of diverse faculties. The most important in industrial conditions are the faculties of acute sensitivity and a ready reaction, the faculties of attention and muscular co-ordination and the faculties of memory and judgment.

It is quite possible that some kinds of data will indicate and express one special faculty more readily and another kind of data other special faculties. It is therefore important to discuss under each type of data—output, accidents, *etc.*, what kind of faculties it is that find expression specifically or pre-eminently in that data.

3. The investigator must beware that variations in data which express variations of working capacity to some extent are not at the same time expressing something else *besides* that capacity. When conditions interfere with and disturb the exact or "pure" correspondence of data with working capacity they render data ambiguous. The investigation must isolate the factor of working capacity in order to exclude other factors likely to effect the data; while one thing is studied other things must be equal, or at any rate well under control. For instance, if the speed of a machine operation fluctuates owing to mechanical causes, the effect of such causes on output or other measures must be thoroughly ascertained and allowed for.

For this purpose two methods of procedure are possible. Particular cases must either be carefully selected where all factors are known and measurable and no ambiguity exists

or need exist, *i. e.*, where data are naturally unambiguous or else subject to control; or, on the other hand, extensive "mass" statistics must be collected yielding a sufficient number of cases to eliminate *in the average* all chance ambiguities that do exist.

Where possible, both methods of procedure should be pursued, one acting as a check on the other. A monograph of the complete working life of one individual giving a detailed causal analysis, is more instructive and teaches how the figures are formed; mass statistics distinguish and describe what is general as against mere individual idiosyncrasies and, moreover, will point the way where detailed causal analysis is most necessary.

To select a situation where all disturbing conditions are absolutely constant or where at least they can be stabilized to render data wholly unambiguous, is difficult except under laboratory conditions. In the factory the output of individuals will vary daily with their daily state of health, their family worries, or the temper of the foreman—factors that are irretrievably inconstant. Hence it is usually necessary to *average* many single observations of each individual's variations and then to average the average of all the separate individuals, and so on—gradually forming a combination of averages, till in the end is obtained a composite figure that is *representative* of the results of normal conditions of bodily and mental health and of normal factory management. If any of the sub-averages entering into the chief average is based on a greater number of observations than other sub-averages it may be *weighted* in proportion to the greater evidence in its support. Thus if the average of thirty observations be 6, and the average of ten observations be 8, the composite weighted average should be, not plain $\frac{6+8}{2} = 7$, but $\frac{(6 \times 30) + (8 \times 10)}{30 + 10} = \frac{260}{40} = 6.5$.

The average may be either the arithmetic mean, the

median or the mode. The arithmetic mean is the average that is most exactly calculable and the most frequently used. It is the sum of the amounts recorded divided by the number of records. The median is the amount indicated on the record placed in the middle when all the records are placed in order of the magnitude of their amounts. The advantages of the median as average is that it is only slightly affected by records having extremely high or low amounts. Thus the arithmetic mean of 5, 5, 5, 6, 6, 7, 22 is pushed by the last item up to 8, but whatever the size of that item the median remains 6. The mode is that amount which occurs most frequently on the records. In the above series the mode is 5. To the ordinary mind the mode represents more nearly the "type" than perhaps any other average.

By means of averaging, the influence of those factors will be eliminated that are not regular accompaniments of the various measures of working capacity, but are only causing chance ambiguities. These factors will influence records first in one direction, then in another, and in the long run they will cancel out. What length of run is required, and over what range of time and place before the individual observations can compose a reliable average, depends mainly on the amounts by which individual observations *deviate* from the representative figure. The formulae for the mathematical calculation of the average of deviation from the averages, the reliability of averages, and all the other simple devices of measurement that are required in this type of investigation, may be obtained in any elementary manual of statistical theory.

CHAPTER IV

The Output Rate

Enumeration

The enumeration of any type of output depends upon its *uniformity* and its *divisibility into units.*

The first task for every investigator proposing to use output as a measure of working capacity is to find *uniform* operations performed throughout the period to be studied. At a large munition factory an attempted comparison of the different week's output of certain girls nominally on the same work was made impossible in the majority of cases owing to the fact that the girls were not really continuously on the same operation. One week a particular girl working on a capstan lathe was set to make one part of a fuse, in another week or even in the same week she was making another part, of quite different complexity, and therefore with a quite different rate of output per hour. Indeed over the whole factory it was only in one 18-lb. shell cartridge case department and in the work of six girls in the fuse department that the kind of output was found sufficiently uniform over a long period for purposes of enumeration.

The investigator should be especially on his guard that products known by the same name are not of slightly different size, or for some other reason do not vary in the effort required to make them. The output of an individual may be recorded on paper, as so many unit "boxes," but when the matter is investigated the actual output will be found to fall

into various amounts of say 2 oz. boxes, 3 oz. boxes, 4 oz. boxes, with no common measure of the respective requirements of each in the amount of activity exerted.

Where the output is thus of various kinds, a sort of common denominator may sometimes be found for all the varieties in the amount of piece wages earned, or where the task bonus system has been introduced in the degree of efficiency attained. The accuracy of this denominator would depend of course on whether the piece-rate or percentage efficiency was estimated exactly proportionately to the comparative effort required of the worker as between different varieties of output. My own experience with the measurement of working capacity by piece rates and by efficiencies, even where these had been estimated by the most careful time and motion study, was unfavorable to the use of such common denominators. In one factory that I visited the amount of task-bonus paid for many processes depended on the percentage of efficiency attained, and much trouble was taken to ensure that 100 per cent efficiency in each variety of work entailed exactly similar effort on the part of the worker. Now in many departments a great fall had been taking place in the efficiency attained. But it was admitted by representatives of the firm itself that this fall was probably due merely to a change from one kind of work to another. At my request a study of this factor was made in one department, and there it was seen that "efficiency" clearly varied according to the variety of work being performed. It seemed impossible to compare numerically the degree of effort required in different work.

This difficulty, of course, in no way nullifies the calculation by piece-rate earnings or by efficiencies where the same kind of output is being produced throughout. If the record of earnings and efficiency is more accessible, by all means let it take the place of the direct output record. Abbé used

the piece-rate earnings in measuring the effect on working capacity of his reduction of hours; but the work of his factory as a whole had not changed in the meantime. It was not, to borrow a phrase from vital statistics, to "correct the work-constitution" of the factory that Abbé used this measure, but, most probably, because the records of piece-rate earnings were easier to compute than records of direct output.

Comparisons of the cost of labor as a common denominator for all varieties of work will give a still rougher measure of working capacity. It does not avoid the discrepancy between comparative piece rates and comparative effort, and in addition raises discrepancies in the actual computation of the cost.

If a worker is employed on different operations it may be possible to select for comparison the output rate of any one operation that recurs regularly at intervals. The difficulty here, however, is that the output rate of the operation that is selected will be affected by the degree of effort required on the various operations preceding it; and at each recurrence of the operation studied, the preceding operations may be different.

Operations that result in a quantity of *units* being produced are confined to what the manufacturers and workers usually call repetition work. How many such units must for statistical purposes be produced per day depends on the period studied. If the hourly output is being compared the repetition must obviously be more frequent than if only the daily output is the subject of comparison. To show variations as between different periods with any exactness at least three units should be produced on the average in each period compared. Sometimes the timing of output is given not as the number of units per hour or per day but as the number of minutes or hours per unit. This, however, is

easily translated to units per period and the same rules as to frequency apply.

Luckily for the investigator, though possibly not for the workers themselves, such frequently repeated work has been increasing under the modern factory system owing to the continual replacement of men by machines and the continual division of labor. Work is stereotyped and work is clearly defined. This applies very particularly to the munitions industry where products have to be made according to government "specifications." The munitions industry accordingly supplies a very fine field for output records.

Appended is a list of a few processes producing enumerable units that are sufficiently repetitive to have been used either by the present writer or by fellow-investigators as measures of working capacity.

Packing Processes.
Straightening rods or cans with a hammer.
Sticking labels on standard-sized cans.
Soldering lids on standard-sized cans.
Filling standard boxes with products.

Assembling Processes.
Assembling links into a chain.
Assembling the fuse of a shell.
Covering middles (i. e. creams) with chocolate.
Joining sides and bottom of standard-sized boxes.

"Working-up" Materials. ("Machining" Processes.)
Sewing belts and buttonholing by machine.
Drilling, boring, *etc.*, parts of shell-fuse.
Lathe-work on standard 18-lb. shells or any standard "parts" of a fuse.

Machine-tending (semi-automatic).
Feeding machine with cartridge cases.
Feeding, emptying and controlling presses.

Type-setting by hand and on typograph.

The same processes or crafts are of course often found in different industries. The munitions industry, for instance, includes many processes found in automobile manufacture.

Expressiveness

Once a type of output is found consisting of a number of units which can be said to vary "up or down" because it consists of a greater or lesser number of units, the next stage is to select such an enumerable kind of output that these variations will be expressive of variations in the degree of working capacity. In the case of measurement by output such expression, if it exists at all, will of course be "congruent," *i. e.,* when working capacity increases the output rate will increase also and *vice versa.*

Where the worker whose capacity is to be expressed is the operator of a machine and the machine sets the pace of work entirely—that is, where the operator neither drives the machine nor controls the starting, stopping or changing of its action, nor guides each unit of material, nor yet is able to vary its flow in feeding it into and emptying it out of the machine—there the amount of output will be measuring mechanical efficiency, not human capacity. Examples of such cases arise where the operator is only watching or minding the machine, as with self-feeding "automatic" lathes or looms that stop automatically when the thread breaks.

Often, however, what is known as a purely mechanical or machine-driven industry is found on analysis to contain many processes where the amount of work performed is closely dependent on human faculties of accuracy, coordination and rapidity of action. In the modern spinning mill, highly capitalized though it is, the writer found several processes subject to the human element, such, for example, as the initial scutching of the raw cotton, where the operator

must keep feeding the machine, and such also, as the emptying of the bobbins from the slobbing frame.

In the making of iron and steel, again, though the huge smelting furnaces, the flame-jetting converters and hearths and rolling-mills seem utterly relentless, there is yet room for human capacity to make itself felt in many of the operations: keeping the runways in the sand open for the molten pig-iron to reach the ladle; taking over the pig-iron to the charger for the converter; filling the charge and preparing "the bottom" of the "openhearth"; and finally placing the ingot accurately on the rollers. All this manipulation is done by tools or by cranes and hoisters, yet behind them is the human eye and the co-ordination of human muscles.

Elimination of Ambiguity

To enable the rate of output to measure working capacity without ambiguity the influence of factors in the industrial situation must be excluded that modify output one way or the other without passing through "capacity" first.[1] Factors likely so to modify output must be kept "constant," so that changes in output cannot possibly be attributed to any changes in these factors foreign to our study.

If, for instance, the output of a factory was falling from one week to another and hours of activity had been raised, it would not be possible to *prove* that the decrease of output had measured a diminution of working capacity unless it were certain that the type of workers and all other factory conditions had remained constant. Otherwise the fall in output might just as well be attributed to a more inexperienced set of hands..

The chief factors that are likely by their inconstancy to disturb or make ambiguous the relation of output and

[1] See diagram above, p. 30.

working capacity are connected first with the type of worker and secondly with certain working conditions. They comprise:

A. The Type of Worker.
B. The Preparedness for Work.
C. The Stimulus to Work.
D. The Feasibility of Work.

A. *Constancy in Type of Worker:* Where a whole factory's output is under observation it is obvious that the total may quite likely be the product of an ever-changing set of individuals or even of an increasing or decreasing number. Where the number is changing the total output should be divided by the numbers employed and expressed as a rate per individual worker. Sometimes the actual number at work cannot be, or at any rate has not been ascertained. Though the number of machines or work-benches is known, yet a few workers may have stayed away all day. In one munition factory I found records giving the total output per shift in each process, irrespective of the number of individual girls working at the time. But as it was to the interest of the management to keep every one of the machines at work, a reserve of girls was kept to be put to work in case the girls usually employed did not appear. Hence it is not likely that the number actually working varied much as between the dayshift and the nightshift on the same date. Mass statistics such as these, though inexact when taken alone, are often useful for checking the results of intensive studies.

Even when known, the rate of output per individual is likely to diverge from working capacity if the employees as a whole vary in their skill or experience.

A comparison attempted by the writer in a munition factory between the output rates of girls working two eight-hour shifts and girls working one twelve-hour shift had to

be abandoned because the number of girls employed on the one shift was only half that on the newly instituted two shift system, hence every second girl in the short shifts had been freshly hired and was inexperienced. The average output for the short shift was lower, therefore, not because working capacity had diminished among certain given human organisms but because organisms of a lower capacity had been added.

Again, at another munition factory hours had been increased in the first year of the war and efficiency had fallen, but the latter was not with any certainty attributable to a diminished working capacity in the same individuals. Besides the increase in the hours of work there was a constant increase in the number of new hands taken on. In one department a great number left to form a new fuse-making department and their places had to be filled by new workers.

It is clear enough from this discussion that the only factory records really free from ambiguity are those specifying the output of each individual worker. The investigator should always endeavor to *compare only similar work from the same worker or group of workers.*

B. *Constant Preparedness:* Even when the type of worker is constant, or when the output of exactly the same workers is studied throughout, certain working conditions are liable by their inconstancy to render the output an ambiguous measure of capacity.

First of all, conditions may not always be *ready* for work to take place. Working time may be wasted and not "filled in" with work. The worker may be waiting

(1) for his material to be brought to him or
(2) for his machine to be repaired or
(3) for power to be connected with his machine.

Conversely, material, machine, and power may be wait-

ing for the worker. He may be late coming in or late getting ready and preparing his materials, or he may be called away for payment of wages or duties about the factory or he may be allowed to leave early at the end of the day or start his tidying-up early.

All these cases of stoppage or tardiness may be considered involuntary waste of time, in the sense that the work did not take place, because physically speaking it could not be performed; the worker and his equipment were not *prepared* for the task.

In his table of output the investigator must note separately the time that was thus wasted involuntarily, and that wasted willingly, as in talking, resting, eating, voluntarily leaving room, *etc.*[1] Allowance should only be made for the time lost *in*voluntarily. The investigator must consider all the hours and minutes the worker was actually ready to work, and only those, and base his rate of output on that as denominator, *e. g.*, if the worker was prepared only for 40 minutes of the hour, his output *rate per hour* should be his actual output multiplied by 60/40. The output is "corrected" in the same proportion as the nominal time was to actual time prepared for work. Thus, where output is reckoned up hourly the table might run somewhat as follows:

Hour	Gross Output	Time Wasted Involuntarily	Corrected Output	Time Wasted Willingly
9–10	20 Boxes	9:30–35 Machine Stoppage..	$20 \times \frac{60}{55} = 21\frac{5}{11}$	Rest 9:10– 9:20
10–11	15 Boxes	10:40–11 Lack of Materials..	$15 \times \frac{60}{40} = 22\frac{1}{2}$	Leave Room.. 10:20–10:25
11–12	12 Boxes	Call to Office at 11:40	$12 \times \frac{60}{40} = 18$	Talk..... 11:30–11:35

The length of the stoppages due to late arrival or early quitting of the workers may be discovered in most factories by an automatic clock which stamps the exact time on a

[1] See pages 97 and 98.

card inserted by each worker as he enters or leaves. These "clocking in" and "clocking out" cards are then usually taken to the wage office.

Stoppages in the course of work can usually only be noted by direct observation. Either the foreman or the investigator himself must be prepared to time any stoppages of more than three minutes' duration.

C. *Constancy of Stimulus:* Now, even where industry is as regularized as it is in the factory, there are many motives playing upon the worker that vary in force from time to time. The worker during working hours must not only be constantly ready and prepared to work but he must be constantly willing and eager to work as well. The investigator must make certain that workers are not discouraged nor "sulking," nor yet controlling their output deliberately.

In one highly organized munition factory records taken by the firm itself on drilling work showed that "the rate of production drops heavily whenever the girl loses confidence in the accuracy of her work." Conversely, "a stoppage due to breakdown, if repaired so as to give the girl confidence, causes an increase of speed." One of the explanations offered for this, namely the desire to make up for the stoppage by faster work, is paralleled by the haste often exhibited at the end of a working period in order to finish off a given operation or complete a given task. All these are cases where the stimulus is inconstant owing to variable moods, and the disturbing factor can be exorcised by averaging out.

On the other hand, a very striking instance of the stimulus being regularly inconstant owing to deliberate calculation was discovered at a large English munition factory. A certain definite amount had apparently become the traditional day's output. If the worker approached this output earlier in the day than was usual he would usually slow

down deliberately to avoid "exceeding the limit." To detect such limitation of output that is not necessarily due to diminished working capacity, the investigator should look back over the records. The stereotyped repetition of exactly the same number of units of output by one worker after another, week after week, is highly suspicious.[1]

In certain cases the incentive to work varies owing to the stress of economic circumstances upon the business pursued. Work in offices, for instance, is subject to special rush hours during the day when the mail must be despatched. Such diverse industries as laundries and telephone exchanges are subject also to rush days during the week, or rush hours during the day, when the demands of their customers are heaviest.

During these times the factory or office management will incite its staff to special efforts and any slackening will lead more readily to dismissal than at other times. As a result, output will rise during the rush. In the office of a munition factory, for instance, a typist working from a dictaphone was found to average anything from 2.16 to 3.83 lines a minute from 5 to 5:45 p. m., when dictaphone records had to be immediately transcribed into letters, but her average at other times was about 2 lines. This did not mean that her working capacity was greater at 5 in the evening but probably that the same capacity was stimulated to greater efforts.

The constant desire to earn high wages can be relied upon as an incentive to work to full capacity, and an incentive strong enough to overcome all the other various motives, only when such wages are paid on a piece basis; that is to say, when the amount of earnings depends on the amount of work done. Investigators are strongly advised not to

[1] See also *Health of Munition Workers Committee Memorandum 18*, pp. 15-17.

make records of output under a time-wage system or even under a piece-wage system that is strongly degressive (where the greater the output the less in proportion is paid in wages) unless discipline and the fear of losing employment and all wages are unusually potent.

Above all, output produced under different *scales* of wages should never be compared. Overtime work, for instance, is often paid at one and a quarter or one and a half times the piece rate paid for work during the normal working day and extra work on Sundays is often paid double. As a result workers will tend to "go easy" in ordinary hours or on weekdays and reserve their strength for the overtime and the Sunday work. Output will vary accordingly but it will furnish no clear indication of working capacity.

A similar variation in what is after all the main incentive in modern industry, namely the "economic" motive, may sometimes be found owing to the maladjustment of different wage systems. In a small munition factory near London, though piece wages were nominally being paid both on an eight-hour and a twelve-hour shift, girls working the short shift were in certain processes being remunerated *in fact* only by a time-wage, since they knew, or thought they knew, beforehand that they could not produce enough output in the shorter hours to earn more than the minimum hourly time-wage which was guaranteed them by a trade-union agreement. On the long shift, therefore, girls were likely to be "trying" much harder than on the short shift.

When the main incentive is not a constant force output data are rendered useless. The degree of inconstancy cannot be measured accurately and the investigator is warned never to choose records under such conditions.

D. *Constancy in Feasibility:* To measure working capac-

ity unambiguously, variations in output must obviously not be due to variations in such foreign circumstances as the quality of the materials and of the machines used in the work or to the quality of the lighting.

Lighting, besides influencing output indirectly through its influence on working capacity, particularly that of the eyes, may affect the ease of operation directly and physically by its influence on the visibility of the material equipment. The Industrial Commission of Wisconsin found that a certain steel plant by merely changing its system of lighting increased its output at night by over 10 per cent, and undoubtedly any excess of output by day over that at night is in part attributable to the greater power and more equal distribution of daylight. In certain processes, however, artificial light can more easily be centered on the work and glare can be avoided.

The same amount of a given kind of output if produced from different machines may have involved quite a different ease of production; and even similar machines will vary substantially in ease of production according as they are oiled, connected with the power, *etc., etc.* The investigator should hesitate, therefore, before classing as identical even similarly named and similar-looking machines. The slightest difference when the machine is at work in the methods of driving, feeding and controlling it and guiding the material will produce vast differences in the feasibility of a given operation.

Raw material, even of exactly the same name, when drawn from different parts of the globe is likely to differ greatly in the ease with which it can be handled—in its softness, malleability, pliability, *etc.* Again, it is well known that cotton thread while being spun breaks less easily in a humid than in a dry atmosphere.

The quality of the raw material supplied may vary also according to the skill of the operator who prepared it.

Thus in cotton-spinning, the number of threads that break on the slobbing frame depends largely on the skill displayed in the drawing processes that just precede the slobbing.

Because of the enormous differences in feasibility of any given output due merely to differences in factory equipment and technique — lubrication, lighting, materials, machines, and also to factory organization (see page 14)—*it is inadvisable for any investigator to attempt to compare the working capacity in one factory directly with that in another.*

Sources of Record

The method of collecting output data that is most likely to be accurate is for the investigator himself to watch a group of workers and note their output, staying in the factory day in and day out, and this method has the advantage of continually suggesting to the investigator new facts of significance and new methods of recording them. For instance, as I watched the output of four girls assembling bicycle chains with a press driven by foot for two days of eleven hours each I observed clandestine meals and rests taken unofficially and how the rests were spent. Further, struck by the constant rhythm of the girls' motions, I was led to some new investigations into the value of rhythm as a stimulus.

However, the personal collection of sufficient output data to establish conclusions would require a whole army of investigators, and even then the presence of the investigator is only too likely to disturb and make unrepresentative the very facts he wishes to secure in their native state, as actualities of industrial life. Indeed I found that the average output of the four chain-assemblers was at a speed considerably higher than usual on the days I watched, being 7.10 chains per hour as against from 5.85 to 6.80 recorded in the books for previous weeks. In spite of a tactful explanation

of my purely scientific purpose, the presence of a stranger making strange notes may have inspired a fear of taking very long rest pauses or of indulging too much in conversation. Where, however, as in "scientifically managed" factories, the workers are accustomed to being time-studied, the disturbance due to this factor will be much smaller.

The method of recording output which is least disturbing to the worker's ordinary attitude and also most easily carried out is by use of automatic registers, of which the cyclometer is perhaps the most familiar type. I have seen clocks or registers attached to machines such as looms, stamping-presses, sewing-machines, where each revolution of the crank producing a unit of output was duly recorded in figures which could be read off whenever required. Some registers are even self-recording; that is to say, instead of being "read off" by human agency they actuate a pen which traces the curve of output on a rotating drum. In view of the low cost of registers and the ease with which they are attached, their use might well be extended.

A method of recording only slightly more disturbing is for a member of the factory staff, usually the foreman, personally to make the record. To the worker the presence of the foreman and his taking of notes are a part of the factory routine; the worker's attitude will not alter much from that of his ordinary working mood.

Such records either personally or automatically collected by the firm may either be initiated by the investigator or may already be in existence when he begins investigating. As the investigator enters the factory for the first time, somewhat bewildered perhaps, he should ask that the output records already collected be shown him. Never should he lose an opportunity of using the documents of industry that he finds ready to hand. He cannot be urged too strongly, however, always to subject these factory records

to a detailed scrutiny. First of all, he should visit the actual operation in the workshop of which the record shows the output. This personal visit, especially if the investigator has even a small knowledge of mechanics, will probably suggest explanations of peculiarities in the records or perhaps show up errors in recording. Secondly, the output record itself should be carefully checked and the same questions put as though the investigator was selecting operations to study for himself. Was the output enumerable? Was it expressive? Was it free from ambiguity, with personnel, preparedness, incentive and feasibility either constant or averaged out? Records when kept in the factory books as a matter of routine often range over a long period and cover a large number. As mass statistics, therefore, they will offer a great chance of averaging out inconstant factors and, even when not entirely free from ambiguity, they may often prove useful in checking intensive inquiries. I have used figures of gross output per machine, irrespective of possible absences of the workers, in a whole department making millions of rifle cartridge-cases per week, to check a comparison of night and day efficiencies based on the weekly output records of *selected* individuals. It was very much against the interest of the firm to have any machines lying idle, so that absences, or at any rate absences without substitution of another worker, were extremely rare.

Seldom, of course, will these records of output have been made by the firm for the purpose of studying working capacity; when they are taken it usually is for the purpose of computing the piece-wages to be paid their workers.

In one munition factory where workers are paid so much per thousand rifle cartridges turned out, with a minimum guaranteed wage of so much per hour, the hours worked and the output on each day are noted down quite simply for each individual in small memorandum books kept by the

foreman, and hours and output are added up for the week.

In another and larger firm, where the wage paid is based on a more complicated system and where the output is more varied, a huge "detail sheet" is kept at the "wages office" and filled in for each individual worker each week, being arranged as follows: columns are provided for the time at which the employee entered and left the works; for the time lost and the time worked for each day of the week. Each of the different kinds of operation the employee has performed is then entered item by item down a column; and opposite each entry is stated the hours worked on that operation and the output, both hours and output appearing under the proper day. Beyond the columns for each day are columns for the hours worked and the output of each operation for the whole week.

These columns contain the whole of the information on the facts of output rates that we require; columns beyond then work out the wages payable for the week from the facts already given.

CHAPTER V

The Consumption of Power

Enumeration

A magnificent opportunity of measuring the working capacity of a whole factory is given the investigator whenever a factory keeps a record of the amount of steam, electrical or other mechanical power consumed in the running of the machinery. The work done by the factory is here enumerable not in units of some concrete output but in kilowatts or horse-power which can measure at any one moment the rate of working and reduce all kinds of output to a common denominator. The watt is the work done per second by force of one volt in driving a current of one ampere and the kilowatt is a thousand watts. One horse-power is the work done per minute by a force lifting 33,000 lbs. to a height of one foot.

Expressiveness

Though one stage removed from the actual output the consumption of power tells the tale of human working capacity no less definitely. Of course the speed must not be set entirely by mechanical forces, which as we have seen also limits the scope of output records, and moreover the use of power as a measure of working capacity cannot be applied to the many manual operations that still exist in industry, where no mechanical force is used. The field of measurement is thus restricted at both ends; only those processes can be measured by power consumption where

hand and machine combine to set the speed. Such processes, however, include the important class of semi-automatic operations, *i. e.* where each unit of material is guided through, fed into or emptied out of, a power-driven machine *by hand,* and also include all such operations where the power-driven machine can be controlled by hand, *i. e.* started, changed in action, or stopped, as on a lathe.

Elimination of Ambiguity

All influences that play on direct output records and tend to make those records diverge from working capacity will naturally also play on the more indirect records of Power Consumption. Throughout the period of record there must be constancy in type of worker, constancy of stimulus, constancy of preparedness and constancy of feasibility. (See page 45 *et seq.*, above.)

Moreover, though power affords a common enumerator for different kinds of work over the whole factory it is useless to compare the consumption per machine if the work as a whole is very different during the period studied or if a different set of machines is employed. Almost every machine and certainly every operation has its own particular efficiency in the matter of converting power into product, while different operations use power according to the effort of the tool against the material rather than the effort of the human worker.

Records of power consumption are a more ambiguous measure of working capacity than direct output records in so far as the record of power consumed varies concurrently with variations in factors other than the output turned out. As a rule electrical power is used by factories not merely to run the machines executing the work on the materials and to drive the shafting and belting connecting engine with machine, but also to light, to heat and to venti-

late the factory artificially; and steam power is often used for purposes still more manifold. Now variations in lighting, heating and ventilating are obviously quite independent of variations in output and in working capacity; and the same applies to the driving of shafting and belting. If any work is to be done at all, however slight, on any given machine the shafting and belting connecting that machine must just the same be run to full extent. It is therefore only that proportion of the total power which is consumed at the actual point of contact of machine and material that can express working capacity unambiguously.

It is fortunately not difficult, however, to find out what the proportion is between the amount of power, or "load" as it is called, used for shafting, ventilation, lighting and heating and the amount used on the material. All that the investigator requires is that the shafting and belting and the light, fans, radiators, etc. be run for a short experimental period without any work being done on materials, and that a note be made of the power used thereby.

An experiment of this nature conducted in two departments of a large munition plant in the north of England disclosed the shafting load to be as much as 5/11ths in one case and 4/7ths in the other of the total power consumed, while in a smaller but more highly organized munition plant an average consumption of 545 kilowatts when the factory was artificially lighted was found to be used for the following purposes:

	kilowatts	*% of Total*
Driving motors and shafting	125	23%
Blowers, Fans and Air Compressor	65	12%
Lighting (when fully illuminated)	95	17%
Machine friction and work on materials	260	48%
	545	100%

In engineering handbooks investigators may find further estimates of the proportions of the total power consumption used for the different purposes. Below is a table showing the proportion used for shafting as between different departments of a machine shop.

FRICTION LOAD DUE TO LINE AND COUNTER-SHAFTS

Department	*Per cent of Friction to the Total Load*
Cam-cutting department	26
Cutting-off department	43
Cuttermaking department	27
Chucking department	26
Light drilling department	23
Heavy drilling department	34
Grinding department	21
Lathe department	25
Milling department	25
Planing department	26
Patternmaking department	17
Jig and fixture making department	37

An attempt made by Mr. H. C. Spillman[1] to analyze still deeper and to exclude the machine friction occurring between countershafting and the tool actually working on the material, disclosed that the line-shafting and countershafting consume 30 per cent of the total power, and the total friction losses absorb 72 per cent of the total power. This makes a 42[2] per cent loss of power from the countershafting to the machine tools, and only 20 per cent of the total power is utilized in doing work, the electrical energy going to waste amounting to 8 per cent of the total power.

Luckily for the investigator such complicated analysis is often not necessary. The power consumed to drive the same shafting and belting is usually constant throughout

[1] "Machinery," London, June, 1913.

[2] *I. e.*, 72-30 per cent.

any given working period; its effect on the measurement of working capacity is merely to render variations in capacity of less force. Thus if working capacity varies between 100 and 150 over a certain period and is expressed in the power consumed for contact with materials, and if when this is at the minimum it is equal to the power used for shafting, the variation in the power used for both purposes will consist half in a variation as 100 to 150, half in a variation as 100 to 100, the result being a variation of only 25 per cent.

The power consumed in lighting, heating, and ventilating on the contrary, is not constant throughout a given working period, but will be varied purposely with the temperature and light prevailing naturally. The resultant record may well differ from working capacity not merely in force but also in direction. The investigator therefore must measure what amount of power is used solely for these purposes and subtract it from the total power consumed. It is easiest for him to choose records taken on warm bright days when perhaps no artificial light is required and no heating. Ventilation will never require more than a small fraction of the total power.

Sources of Record

Records of power consumption are usually kept in the engine-room. Quite a high proportion of factories use them for purposes of estimating or checking expenses.

Records may consist either in readings from the meter at any moment or series of moments, or they may consist of a continuous curve traced automatically by the needle of a self-recording instrument, similar to that used in barometric and thermometric studies. In the case of self-registering instruments care should be taken that they are properly adjusted, *i. e.* that when no power is consumed the needle really records 00 kilowatts.

CHAPTER VI

The Accident Rate

Enumeration

No data can be treated statistically unless consisting of a number of similar uniform units. In the data of accidents the statistical unit is each individual accident. An industrial accident is a sudden injury to a worker that was not premeditated. It usually does not include poisoning, strains, sprains or fainting. In some factories with a "welfare" installation every case merely requiring first aid is considered as an accident; in other factories, less amenable to hygienic innovation, "accidents" are only those injuries which are serious enough to entail a report to the governmental inspectors. In the United States, much as these definitions differ in the different states, reportable accidents are usually limited to those resulting in at least one day's absence from work. However, to the scientific investigator it does not matter what definition of accident is adopted *so long as the same definition is retained throughout the period studied.*[1] Any changes in the standard of reporting, such as a greater strictness in keeping records, that is effected during the period studied will of course render the data a very doubtful measure of working capacity.

Expressiveness

Of accident variations which can be accurately enumerated we must now select those which will express variations in working capacity. In the case of measurement by accidents such expression, if it exists at all, will be inverse, *i. e.* when working capacity increases the accident rate will presumably decrease, and *vice versa.*

[1] See footnote page 35.

Owing to certain peculiarities in the accident variations actually observed there has been much controversy among investigators as to whether the accident rate expressed human working capacity at all. It is certainly true that many classes of accidents to men in the factory will occur that can be attributed to no individual's fault, or at any rate to no individual's fault *at the time*. Accidents of this nature include explosions and electric shock, accidents due to animals and all accidents due to previous carelessness in arranging materials and equipment. However, it is very difficult to draw a hard-and-fast line between accidents "humanly circumstanced" at the time and "mechanically circumstanced"; the cause is usually due to a combination of the two elements in different proportions. In the second Report (1916) of the Committee of the British Association on Fatigue from the Economic Standpoint the writer made some attempt to grade accident occurrences according to the weight of the contributory human element. Accidents, being unpremeditated, must be due to some unusual circumstance either in the movement or position of the human body or in the movements or position of some material object at the time the accident occurred. The order in which accidents may be graded, beginning with those where the human element was least responsible, is, therefore, somewhat as follows:[1]

A. Accidents due to unusual action of the material: first, which no human capacity could have foreseen or escaped at the time; second, which great attention might just have foreseen; third, which through quick reaction might have been escaped; fourth, which either by attention might have been foreseen or by quick reaction might have been escaped.

B. Accidents due to unusual action on the part of the

[1] For the detailed argument and a description of typical accidents the Report itself should be consulted. See *Proceedings of the British Association for the Advancement of Science*, Section F, 1916.

worker owing to his lack of co-ordination or to positive inattention; fifth, extenuated by unusual conditions surrounding the work; sixth, without such extenuation.

C. Seventh, accidents due to unusual action of material due in turn to the injured man himself *e. g.* shell dropped by man on his own toes.

The most expressive measurement of human working capacity through accidents in the factory would therefore be afforded if only those grades of accident were chosen where the human element predominates — say grades 5, 6 and 7.

There is, however, some evidence that *most of the accidents that do take place in factories are distinctly of the more humanly-circumstanced grades.* Below is the distribution over the different grades of 204 accidents occurring during 1915 at an English munition factory employing a large number of hands, the figures being obtained by a personal examination of the individual accident reports required by the government; and of 1069 [1] accidents occurring in the Lancashire cotton industry, particularly in the spinning rooms, cardrooms and weaving sheds.

These figures are based on the following particulars presented by the Federation of Master Cotton Spinners' Associations to the British Departmental Committee on Accidents in 1911:

	No. of accidents	*Assignable to grade*
Knocking against machine	154	5 or 6
Kicking spinning carriage slip	134	5 or 6
Falling or making false step	200	5 or 6
Caught, e. g., trapped between rollers	238	5 or 6
Cut by tool in use, etc.	139	5 or 6
Breakage (of strap, etc.)	6	1 or 2
Cut or hit by falling object	59	1 to 4
Splinters	97	4
Scalded and burnt	19	1 to 4
Climbing on headstock	23	5 or 6
	1069	

[1] Including "Miscellaneous" the total was 1,362.

Grades in Order The least humanly circumstanced first	Munition Factory		Cotton Industry	
	Number	%	Number	%
1st	2	1	61	
2nd	22	11		
3rd	28	14	....	17
4th	19	9	97	
5th	15	7		
6th	71	35	8881	83
7th	47	23	....	....
Total.....	204	100	1069	100

In the American Journal of Sociology for 1911, E. S. Bogardus [3] sets himself the question, "What are the concrete immediate conditions preceding accidents—the 'modus operandi' of the general causes in bringing about accidents?" Examining 2,666 accidents occurring in the state of Illinois in 1910 he finds that 463, or 17½ per cent, were "beyond the control of the injured," and 2,203 or 82½ per cent were avoidable by the injured.

Elimination of Ambiguity

A. *Constancy of Rate of Output.*—The chief factor likely to disturb the accuracy of the accident record as a measure of working capacity is the rate of output. Variations in the rate of accidents per hour are an ambiguous measure if the rate of output is also varying, because output variations are likely to condition a corresponding variation in accidents. The correspondence of output and accident rates per hour is likely to be in exact proportion, in so far as the greater

[1] These accidents unassignable to any one grade but one of two—description incomplete.

[2] Seventy-eight accidents unassignable to any one grade, but either 1st, 2nd, 3rd or 4th, are included.

[3] *American Journal of Sociology*, 1911, pp. 17, 206-222, 351-374.

the output the more frequently does the operator pass through certain danger points—the greater, in a word, is the exposure. If instead of pushing his material under a circular saw forty times an hour the operator pushes it under fifty times, the exposure to accident is increased just by one and one-quarter times.

In so far as the accident rate per hour varies directly and exactly with the output rate, the ambiguity may be overcome by taking as the measure of working capacity not the accident rate per *hour*, but the accident rate per unit of *output*. The investigator should bring together and compare the output record per given period of time and the accident record for the same time, and for the same individuals or the same factory.

Where the output of certain selected individuals only is recorded, such a comparison is impossible since the number of accidents among a few individuals would not be sufficient for statistical reliability. But where the output of a *whole* factory is recorded, as is possible through variations in consumption of power, an admirable basis exists for the comparison. A highly organized munition factory supplied the data for the following table. For each hour of work for six months the number of accidents is recorded and beside it the relation each hour's accidents bear to the average hourly number is expressed as a percentage; similarly the electrical power consumed—first daily amount, then percentage of average. In the last column is the ratio for each hour of accident percentages to power percentages. This forms, perhaps, the subtlest, inverse, measure of working capacity yet devised.

All factors rendering output records ambiguous will indirectly do the same to accident records. Incentive, preparedness and degree of feasibility through lighting conditions of materials and machines, *etc.*, must all be kept constant.

Hour	Accidents		Power Consumed		Ratio of Accidents Percentage to Power Percentage
	Total	Percentage of Average	Kilowatts	Percentage of Average	
8– 9....	113	87	396	97	.90
9–10....	131	101	411	100	1.01
10–11....	144	111	407	99	1.12
11–12....	149	115	414	101	1.14
2– 3....	103	79	414	101	.78
3– 4....	113	87	413	101	.86
4– 5....	156	120	413	101	1.19
Hourly Ave.	130	100	410	100	1.00

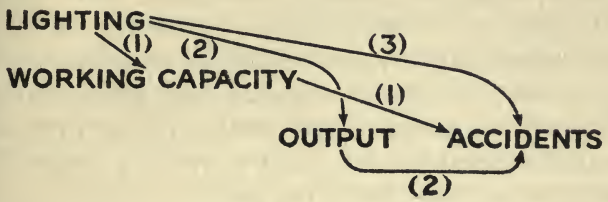
Lighting and incentive, however, both probably play a larger part in influencing accidents without "passing through" working capacity than they do in influencing output, while the investigator into accident records has to pay particular attention to the constancy of preparation.

B. *Constancy in Stimulus.*—The accident rate per hour is likely to fluctuate in correspondence with the output rate—but out of all proportion to it, if the rate of output is in any way set beyond the workers' powers. In such a case the worker is only too likely to feel rushed or get "fussed" and flurried and to poke his hand into unaccustomed places. Probably, grades 5 and 6 and 7 would be most affected by this overspeeding, namely those accidents that are due in some degree to a loss of muscular control.

An interesting suggestion based on experience at the Watertown Arsenal has been brought forward by certain scientific management experts that *under*-speeding of output may also increase the accident rate per hour owing to the slackening of attention and of reaction-times.

C. *Constancy of Lighting.*—The influence of lighting on

accidents contains conflicting elements and we shall have to call a diagram to our aid.



Arrows represent influences, and there are three chains of influences (1), (2), (3). (1) The worse the lighting, the more working capacity will tend to diminish owing to eye-strain, and hence the greater the number of accidents. At the same time bad lighting (2) has a direct influence in decreasing output—hence, as explained above, less accidents—and also (3) has a direct influence in decreasing the visibility of danger points—hence more accidents.

The net result of the influences of lighting on accidents is illustrated in a diagram published by the National Electric Light Association, comparing the monthly proportion of darkness, cloudiness and sunlight in the city of New York with the monthly number of fatal accidents in eighty industrial plants for three years. Both the accidents and darkness reach a maximum around January and a minimum around July. Similarly the British Departmental Committee on Lighting in Factories and Workshops reported in 1914 that "in all tables there is a general increase in the accident rates for the period of artificial lighting. . . . Accidents from all causes were 29 per cent more numerous in artificial light than in daylight."

D. *Constancy of Danger of Operation.* — In examining the accidents occurring in iron foundries a huge increase is always noticeable late in the morning and late in the after-

noon. A very large increase is noticeable at the same times in all accidents due in the official terminology "to the nature of corrosive materials and liquids, acids, alkalies, slaking lime, *etc.*" Thus, in Ohio, for the year 1915, accidents from this cause reached a maximum between 10 and 11 a. m. *more than twice as high* as the next highest hour's accidents in the morning, while in the afternoon the maximum was attained between 4 and 5, when, in accidents due to other causes, there was a big drop.

The explanation lies in the fact that iron foundries follow a regular procedure in their work. Early in the mornings and afternoons they make the molds to receive the molten metal; late in the two spells they cast or pour the molten metal into the molds. Now, casting is far more dangerous to life and limb than making molds out of sand; the increase in accidents does not measure a fall in working capacity so much as a change in the danger of the work. The same applies where a factory is gradually perfecting the guarding of its machines and other safety devices and decreases accidents over long periods by decreasing the physical danger.

The investigator, therefore, is bound to reject all comparisons of the accidents occurring in periods between which there is a definite inconstancy in the physically conditioned danger; either where the same work becomes over long periods less or more dangerous or where regularly at different times workers move from one kind of operation to another, involving a different degree of danger.

Sources of Record

To record a number of accidents sufficient to show definite variations, and to average out chance occurrences, it is clear that the investigator cannot stay in the factory waiting expectantly for accidents to happen. He must rely on the past records kept by the firm itself.

Luckily for him, as well as for the workers, most governments have passed legislation requiring information of the occurrence of all serious accidents in industry. For this purpose the governmental authorities have devised blanks which the employer is obliged to fill in as soon as a serious accident occurs in his factory. Among the questions required to be answered are usually found (1) the circumstance of the accident and (2) the date and time of day when it occurred; often, too, the employer is required to state (3) when the workman began work on the day on which he was injured, and the English Home Office has even added the question (4) as to when the workman began the spell in which he was injured.

All these questions are of the utmost importance to the investigator into fatigue. The answer to (1) tells him how far human working capacity can be held responsible, the answers to (2), (3) and (4) how much activity the workman had been exercising before he fell a victim.

These governmental inquiries are often found duplicated by the firm itself for its own purposes. In this case lesser accidents are usually included. Thus, the government of most states usually only requires the filling in of a blank when the accident results in the victim having to stay away from work several days or when it was due to preventable mechanical cause. The firm, on the other hand, may make a note of every little scratch requiring "first aid." In this case care should be taken that the time of day be always noted, and that this time be not that of treatment or redressing, but of the actual occurrence of the accident.

The present schedules for official reporting of accidents would be more useful if in every instance the actual times of beginning and stopping work and of the occurrence of rests were declared for each factory or shift. As things are, it is impossible to discover from official records how many men

are at work at any given hour. A low record of accidents at the start or a fall in accidents at any period may therefore be due solely to a decrease in the numbers actually at work. For this reason the records of the individual factory where the exact hours of labor are well ascertained are far more valuable than state records where, owing to the occurrence of unemployment, even the average number employed in any week is unknown. Even within one factory, however, workers may be employed at different times, and in that case it is necessary to record accidents occurring under each time-schedule separately. An accident occurring at 10:25 a. m. will be in the third working hour for the man who came on at 8 o'clock, but in the fifth working hour for the man who came on at 6 o'clock; and if there is any purpose in timing an accident, it is to obtain its position within the working period.

The value of a report for a time tabulation can only be complete if firms were required, when filling in the government form, to make a special record not merely of the *time* of the occurrence of the accident but also of the *hour schedule* under which the injured man was working. Thus a report might run:

Accident occurred: 10:25 a. m.
Hours of labor of injured person: 6-11; 12-5.

Attempts that have already been made by various government departments, notably the Industrial Commission of Wisconsin,[1] the British Factory Department[2] and the German *Reichsversicherungamt*,[3] to tabulate accidents according to working hours have all failed to indicate the state of working capacity any less ambiguously than tabulation

[1] Report for 1913 and 1914.

[2] *Annual Reports of the Chief Inspector of Factories*, 1910, 1911, 1912.

[3] *Amtliche Nachrichten des Reichsversicherungsamts*, 1910.

according to "clock" time, because the number of men actually at work could only be roughly estimated. The writer discovered in the case of one of the British Factory Department's working-hour tabulation that in the whole working day there were only two hours, the first working hour and the ninth, when workers were not taking meal-intervals of some kind, somewhere or other in Scotland, the north or the south of England.

CHAPTER VII

The Proportion of Spoiled Work

Enumeration

The difficulties in enumerating the proportion of spoiled work arise from the fact that the amount of spoiling is a matter of degree and often also a matter of opinion. Usually the quality of any product can be placed only in very rough classes and the standard of each class may vary with different examiners and even the moods of one examiner.

Often, however, the standard is set physically by "gauge." Rifle cartridges, for instance, to avoid rejection by the examiners must be able to pass through one size of hole in a gauge and not a size just minutely smaller.

In the munition industry where accuracy is of such vital importance quite as many employees are engaged in gauging the output as will be actually producing it, and every single unit of the output—not merely samples—will be subjected to the process. By material gauges output will of course be divided into but two classes; passed and rejected. Well known processes yielding also an enumerable percentage of spoiled work are typesetting and typewriting. An interesting record was presented by Dr. Pieraccini at the First International Congress on Industrial Diseases at Milan in 1906[1] showing the average number of errors of four typesetters at a printing house in Florence in the different hours of the day.

[1] Goldmark, *Fatigue and Efficiency*, part i, p. 135.

Expressiveness

Like the accident data, variations in the proportion of work spoiled may be expected to measure variations in working capacity inversely. That is to say the increases in working capacity will be measurable by decreases in the proportion of work spoiled.

The particular working faculties that variations in the proportion of spoiled work will express are probably often the same as those expressed by accident variations. Spoiled work, as so often in the case of accidents, is the concrete expression of inaccuracies due to weak muscular control and a lack of attention. Though quick reaction and keen sensitivity which is so decisive in escaping accidents probably play a less important role in lowering spoiled work, they are still of the greatest importance in preventing mistakes due to lack of vigilance and care. Bad judgment and memory are indicated as fully in spoiled work as in accidents; while a quick rate of movement, a quick bodily rhythm, will also increase, if anything, the proportion of spoiled work as that of accidents. Where the proportion of spoiled work is unobtainable, therefore, the more frequently recorded accident data may often be substituted as a measure of bad workmanship.

Elimination of Ambiguity

Where the measure of working capacity is a ratio, factors affecting both denominator and numerator equally will not disturb the accuracy of the measure. In this case the state of preparedness will tend to affect gross output and the number of spoils equally, thus keeping the ratio of the two constant. Thus if workers do not arrive in time there will be less output but also less spoiled work. If only the workers remain constant and the stimulus is not varied, the outstanding factor likely to disturb the correspondence of the

proportion of work spoiled and working capacity is that of feasibility. If the quality of the material or the machine-tools (punches, dies, drills, etc.) varies or the machine itself is subject to faulty functioning, then variations in the proportion of work spoiled are ambiguous as measures of working capacity. Similarly, the condition of lighting and the visibility of the material may prevent a true measure of working capacity.

Sources of Record

The greatest difficulty in the measurement of working capacity by spoiled work is the paucity of adequate records. It is almost impossible for the investigator himself to examine a sufficient amount of output to secure a reliable average of spoils, except where the proportion of spoiled work is very high and output consists of many frequently repeated units per hour. The firm itself usually does not consider it worth while to track down the exact time at which spoiled work was performed. While some of the spoiled work is detected by the worker himself, usually the greater part of it is rejected later on by the special gaugers or inspectors and at that stage the time at which the mistakes were committed and even the identity of the worker responsible for them are no longer recorded or remembered.

The investigator, therefore, will usually have to try and induce the firm to keep a special record for his purpose.

QUALITY OF WORK

In addition to spoiled work some other varieties of measure may be brought under the general heading of quality of work. These methods of measuring are all too rarely used, but they are of great importance from the fact that they can often be undertaken in those operations where the output itself is not enumerable or expressive. Each variety, however, is subject to such different difficulties that we

must content ourselves with one example, illustrating the quality of vigilance.

A highly organized munition firm in the north of England initiated an investigation for the purpose of "determining the most economical number of auto machines which can be worked by one operator." At that time six B and S automatic lathes were supervised by one operator with an assistant to feed-in the material, in the shape of bars, and to gauge the work. When a machine was found to be producing incorrect work it was stopped by the assistant gauger; the operator then attended to the machine, replacing or adjusting the tools. The number of tools replaced in each hour of the shift was noted, on the theory that the higher the assistant's working capacity the more tools—other things being equal—he would find to be faulty and would ask the operator to replace. In the result it was reported that the capacity of the assistant had considerable effect on the variations in the number of tools set. In the mornings of the day shift he made a careful scrutiny of the work from each machine, usually stopping entirely four out of the six machines; after tea his inspection of the work was not so keen.

"A considerable number of tools was set in the mornings, due partly to the energy of the assistant in discovering errors in the work. After tea the number of tools replaced continued to diminish, due partly to poorer light and partly to fatigue on the assistant's part."

Where records of spoiled work are not obtainable separately it will often be found that the output that is recorded refers only to good quality work passed. This measure obviously combines the properties and difficulties of the output and spoiled work measures. Unless the proportion of work spoiled is very high, however, the measure will conform more closely to the output than to the spoiled work rate.

CHAPTER VIII

The Proportion of Sickness and Unrest

In the opening chapter of this book it was pointed out that if allowed to predominate too long, fatigue may ultimately affect the health of the worker. Moreover, as is pointed out in the Health of Munition Workers Committee's Memorandum No. 10, "an undue proportion of sickness in any group of workers usually represents, among those not actually sick, lessened vigour and activity." Sickness records, therefore, probably indicate an extreme stage of fatigue among a few and a diminished working capacity among many.

Sir James Paget remarks that "fatigue has a larger share in the promotion or permission of disease than any other single casual condition you can name."

Whether it promotes certain types of disease more strongly than others, remains still a matter of conjecture among physicians. Probably functional nervous disorders and possibly the so-called degenerative diseases attacking the circulatory, urinary and nervous systems are more likely to run a parallel course with diminished working capacity than are other human maladies. It is, of course, untrue to say that contagious diseases can be caused primarily by long or intense activity, but that even here it is one of the predisposing causes is now generally recognized.

Cognate to physical sickness is the mental dissatisfaction to which the phrase "industrial unrest" has drawn attention. The hypothesis of a close connection between unrest and fatigue needs no special justification here. It is endorsed by numerous official reports, such as that, for in-

stance, of the British commission appointed June 12th, 1917, to "inquire into and report upon the causes of industrial unrest."

The form in which sickness and unrest among industrial workers lies recorded is fourfold: (1) the factory records of absences and lost time on the part of employees; (2) the records of labor unions, establishment funds, friendly societies, mutual-aid associations, *etc.*, paying benefits to sick members; (3) the official mortality and morbidity statistics of national, state and local governments; and finally (4) the rate at which factories are found to lose and replace their employees—their labor turnover.

These types of records are to some extent interrelated, and they may also be used to check one another's evidence. For instance, on the one hand an employee may definitely leave his factory, but without announcing his intention and be marked for the first two or three weeks merely as "absent" instead of as part of the turnover. Thus the proportion of absences and the rate of turnover depend in different factories on the period of grace allowed before the employee's name is taken off the payroll. On the other hand, the reasons for lost time and absences in any factory are often discoverable in the local records of sick benefits or in morbidity statistics for the district; the three forms of information are supplementary in measuring working capacity.

I. ABSENCE FROM THE FACTORY OR "LOST TIME"

Expressiveness

The time lost by employees in a factory is not all due to sickness nor even to the general feeling of tiredness induced by long and intense activity; the worker may be absent for any reason he chooses with or without the "leave" of the management. Absence without leave and without certified sickness is usually known as *bad time keeping*.

Yet on the whole it would seem that sickness or tiredness causes the greatest portion of absences—as far as the factory records permit us to judge. In a large American factory obtaining full information as to the causes of absence 75 per cent was found to be due to the sickness of the absentee. Professor Thomas Loveday, the author of a study on the causes and conditions of lost time, included in the British Health of Munition Workers Committee's Report,[1] has found most factory records distinctly erratic in the matter.

Of firms which keep a continuous record of lost time only a small minority attempt to determine accurately what proportion is due to sickness, or to distinguish accurately between avoidable and unavoidable loss of time. In some factories no distinction is tabulated at all; sometimes it depends wholly on foremen's opinions; sometimes absence is classified as sickness only if a medical certificate is handed in, and certificates are carefully demanded; in other factories the word of trusted employees is accepted, and their absence classified under sickness; in others, again, their word is accepted, but their absence, in default of a certificate, is reckoned under bad timekeeping. Here all absences for less than two or three days are counted as bad timekeeping, but certificates are demanded after long absence; next door longer absences are simply assumed to be unavoidable, except in the case of notorious slackers.

In those cases where the causes of absence have been well recorded Professor Loveday finds a higher proportion due to sickness than is commonly supposed, and in summing up he states emphatically that nearly all records understate, and most records understate greatly, the proportion of lost time due to sickness and other unavoidable causes. He studied for twenty-two weeks one metal-working factory with 1,200 employees where:

[1] Reprinted in *Bulletin 230 of the U. S. Bureau of Labor Statistics*, pp. 42-95.

In most weeks of the record there was much work overtime, especially on Sundays. The figures for sickness referred to well-authenticated and for the most part to certified cases only, and accidents were left out of account; there was an inducement to employees to send in certificates when sick, and the record of sickness was carefully kept. The normal dayshift week was 53 hours and the nightshift week 60 hours.

The results showed that:

In every week recorded save one the proportion of lost time, apart from absences with leave, due to sickness alone is more than a half, and in most weeks it is over 60 per cent, whilst in all weeks certified sickness and leave together account for more than half the total time lost, and in all weeks save four they account for over 60 per cent of it and twice for over 70 per cent of it.

Professor Loveday is doubtful, moreover,

. . . whether even the careful records kept by the firm to whom these figures refer do complete justice to the facts. There remains the possibility that some part of what is reckoned as "bad timekeeping" is due to fatigue and minor ailments which are genuine enough, though no one would ask for or give a medical certificate in respect of them. If that be so, the curves of "bad timekeeping" and of sickness will tend to move in the same direction.

Examining the figures for each week Professor Loveday finds that "this tendency is apparent: the curve of 'bad time-keeping' does on the whole move in the same direction either as the curve of sickness or . . . as the curve of sickness and leave combined." He concludes "that the figures of 'bad time-keeping' include some absences which should be attributed to a sort of invalidity rather than to slackness."

Professor Loveday describes a still more detailed test of

the proportion of absence due to sickness or "some sort of invalidity," and since it is of great importance that this proportion be confirmed by further investigation, we give his method in full:

In the attempt to ascertain by a comparison of curves whether the figures of "bad timekeeping" include absences due to physical disabilities of a minor kind, it is more important to notice whether the curves rise than whether they fall concomitantly, especially when hours are long, for the factors which first produce absences deemed avoidable may go on to produce definite sickness, and thus the curve of bad timekeeping may fall whilst that of sickness rises, simply because those are now declared sick who were previously "off-colour." In other words, it is sometimes necessary to observe whether a rise in the bad timekeeping curve is followed, rather than accompanied, by a rise in the sickness rate. In the records of one factory employing about 950 males I examined the figures for 58 successive weeks. After setting aside 8 weeks in which they were seriously affected by holidays, I found that in the remaining 50 the curve of bad timekeeping rose 24 times. In 13 of those 24 weeks the rise was accompanied by an increase of recorded sickness; in 7 weeks by a fall; whilst 4 times the sickness-rate was unchanged. On 6 of the 7 occasions when the rise in bad timekeeping was accompanied by a fall in sickness, and on 3 of the 4 occasions when there was no simultaneous movement in the sickness-curve, the amount of sickness increased in the following week.

Professor Loveday examined the lost time of three other factories where timekeeping was reasonably good and the records carefully made. In every case *the unavoidable loss* was *more than half the* total loss. In one factory with 270 males and 290 females for sixteen weeks the percentage lost unavoidably was 65.7 per cent for men, 75.8 per cent for women; in the second, with 240 men for twelve months, sickness alone accounted for 54 per cent of total lost time;

in the third, with 130 men for a month, sickness accounted for 46.7 per cent; unavoidable causes generally for 59.9 per cent.

Enumeration

What is meant by the proportion of time lost by absence to total working time is somewhat different in different factories. Some factories measure merely by the number of men losing a definite amount of time per given period, divided by the total number employed, but most calculations are based on the aggregate time lost distributed over the whole staff. The records are usually drawn up every week and the unit may be hours, days or quarter of days. This latter unit is only used where, as in England, factories work a quarter of the time before breakfast (*e. g.* 6-8 a. m.), when men are peculiarly liable to be absent; the usual unit is the hour.

Different methods, also, are used in arriving at the numerical ratio that is to represent the absence percentage. To formulate a standard uniform ratio for purposes of comparison requires the following analysis of factory hours:

Let N be the scheduled normal working hours, O all scheduled overtime and Sunday work, and A the hours lost by absences

As—through sickness unavoidably,

Al— { through other adequate reasons and by leave of the management, unavoidably,

Au—unaccounted for—avoidably lost.

Then the ratio expressing the proportion of lost time may have as denominator either N or N + O (gross scheduled hours normal or normal plus overtime) or N — A or N + O — A (*actual* net working hours normal, or normal plus overtime). Professor Loveday makes most frequent use of a denominator based on normal hours only and halfway between the gross and the net calculation, namely, N — (As + Al), *i. e.* gross scheduled normal hours minus

hours lost unavoidably by leave or through sickness. These he calls the "practically possible hours."

His exclusion of overtime hours (O) from the denominator seems somewhat arbitrary and makes comparisons hopeless between different factories where, according to what is the definition of "normal" hours, N and O may be found in most varying proportions. It is, after all, the *total* hours worked, $N + O$ or $N + O - A$, quite apart from their classification as normal or abnormal, to which lost hours should be proportioned. However, where overtime is worked by only a part of the employees and total hours are difficult to compute, the investigator must rest content with normal scheduled hours for denominator.

The numerator of the ratio may either be A, the gross hours lost by absence for any reason avoidable and unavoidable, known or unknown, or Al + As, those hours definitely known to be lost unavoidably by sickness and other adequate reason (usually with leave of the management); or else As, only those hours actually lost by reason of sickness. The most accurate measure of working capacity is of course provided by this latter—where it is possible to secure the necessary information.

The ratio whereby lost time percentages can best measure working capacity is therefore $\frac{As}{N + O - (Al + Au)}$. Where records are defective the investigator must often content himself, however, with the rough measure $\frac{A}{N}$, or at any rate something near to that.

Elimination of Ambiguities

Constant Type of Worker.—Some types of workers will usually lose more time by absence than will others. Women, for instance, owing to their monthly periods of sickness, might be expected to lose more time than men, though on

the other hand they are probably more conscientious and will lose less time by slacking.

How " slack " the type of worker, depends mainly on the standard of discipline maintained in the factory. If there is laxity in examining the reputation of men before hiring them or if there is hesitation in discharging those who keep bad time, then *pro tanto* a higher percentage of absentees must be expected. At an emergency such as the outbreak of war in England when munition factories were compelled to secure hands in a hurry from any and every quarter and could not afford to dismiss men lightly, a type of worker more often absent may be expected.

The distance at which the worker lives from the factory and his mode of transit is also important. A factory constantly increasing its employees will have to draw from sources further and further away and more and more dependent on the state of the weather and the condition of the transport facilities.

Constant Stimulus.—Special rates of pay at special times will, of course, encourage good attendance then, in comparison with other times. At an English munition factory that the writer studied, an extra bonus was paid for Sunday attendance and the hours of work started later on Sundays than on weekdays, allowing workers an additional hour or two in bed without sacrifice of reputation. As a consequence the proportion of Sunday absences was found to be about one-eighth the average weekday proportion, but there was nothing to indicate that working capacity was more feeble on weekdays than on Sundays. The stimulus may act conversely through the greater desire to " play " outside the factory at some times than at others. The day after payday, for instance, will quite likely average high absences when those workers who are without family responsibilities quite naturally want to spend their earnings. Common sense

suggests, and Professor Loveday's observation confirms this, that just before a holiday or vacation workers will be trying to save money to spend in recreation, and attendance will be especially good.

Again, if the discipline of a factory has varied and the action of the management in dismissing workers for absences is less or more severe, then corresponding variations may be expected in the proportion of absences.

Patriotic enthusiasm, as Professor Loveday points out, will stimulate men to keep at work when they are convinced of its urgency, even though they are unwell and really need a rest. As the obvious urgency of work varies, so inversely will the proportion of lost time—and this quite apart from measuring working capacity.

Sources of Record

The lost-time records of different factories differ very greatly in form. Professor Loveday recommends the following blank, which can easily be simplified where Sundays, nightshifts or overtime are not worked:

WEEK ENDING .....

Shop or Department	Number employed	Number of Normal Hours actually worked		Number of Hours worked Overtime		Number of Hours Lost		
		Dayshift	Nightshift	Weekdays	Sundays	Avoidably	By Sickness	By Leave

As for the accuracy of the facts recorded,

It might be expected that the most accurate records of un-

avoidably lost time would be those based on the records of foremen or officials who have satisfied themselves concerning reasons offered for absence. In fact, however, such records are not very trustworthy except where some superior official, e. g., a departmental manager, takes an interest in the matter. . . . Foremen vary in strictness, and sometimes in personal preference; and those employees who are trusted . . . often fail to report their quite valid reasons for absence. Moreover, in large factories foremen often forget to enter a note of sound reasons, which accordingly never reach the time office.

Professor Loveday further suggests that

An easy and frequently useful test of the accuracy of sickness-records is to compare the number of absences for a whole week recorded as due to sickness with the number of absences for shorter periods so recorded. It is common experience that one is more likely to be ill for a day or two than for a week, and this experience is reflected in accurate records. . . . About 3 per cent of the employees in one factory lost a whole week from sickness in May and June, 1916, whilst nearly three times as many were sick for shorter periods. In another factory the average figures for the weeks of May were—absent sick the whole week 2.9 per cent, less than the whole week 4.4 per cent. If then weeks lost by sickness are found in records to equal or outnumber the shorter periods, it is probable that employees are not troubling to report genuine sickness unless it is worth their while for other reasons to obtain certificates.

2. HEALTH INSURANCE RECORDS

To find the prevalence of sickness in any industry or factory where the length and intensity of activity is definitely known, reference may be made to the records of societies paying benefit to or "insuring" their members for temporary disability and ill-health where these members are drawn exclusively from one factory or, at any rate, from one industry. The last condition is satisfied by the labor

unions, and the first condition by establishment funds managed either by the employees of one factory or by the management singly or in co-operation with employees.

The most famous use of the establishment funds as a measure of working capacity was the investigation at the English Chemical Works near Liège,[1] where a reduction of hours in the factory saved the fund from bankruptcy and established a profit. The figures of labor unions have been used statistically to measure many social forces but not yet to measure industrial fatigue.

Enumeration

To enumerate variations in individual working capacity uniformly several different measures have been adopted. Whatever the measure, whether it be the number of members sick at any given moment or on the average, or the amount of the benefit paid at any one moment or on the average; all of these must be divided by the total membership—yielding a quota per head. The Cigar-Makers International Union of America, for instance, exhibits the cost *per member* per year of the sick benefits paid in the last 36 years and other trade unions publish figures every month.

Where the average number of members sick over a given period is used as the numerator, the quota will not be so much affected by members ill for a long time as where the benefit paid is used as the numerator. Each case of sickness, whether just a temporary tiredness or a dangerous disease, but both equally liable to be predisposed by fatigue, will count the same, unless it continues over several of the periods averaged. However, most societies limit temporary invalidity benefits to twenty-six weeks' duration, so that in yearly averages there could be no duplication and in monthly averages not very much.

[1] Goldmark, *Fatigue and Efficiency*, V, § 5.

Elimination of Ambiguities

The figures of all benefits paid out for sickness are liable to diverge from actual sickness for the following reasons:

(1) The *claim* of the member may vary with the comparative stimulus to work or to play. If wages in the factory have risen compared to prices of food, any member who is only feeling slightly unwell and on the margin of doubt how to act may finally decide to stay at the factory and continue to earn a good living.

In periods of booming trade and good employment attendances at the Out Patients Department of the London Hospital have been found to diminish. For instance, during 1908, when the percentage of unemployment in England (published in the Board of Trade Labour Gazette) rose from about 5½ to over 9, the monthly attendances rose from 5000 to nearly 7000; in 1909 unemployment fell gradually to about 6½ per cent, and the attendances to under 6000; about mid-summer, 1913, the figures had dropped after various fluctuations to 1.9 per cent and 3,600; early in 1914 both curves rose again; and in 1915, as unemployment fell away to under 1 per cent, the attendances were once more reduced below 4000.

Professor Loveday considers this parallelism of good trade and infrequent visits to the hospital due mainly to the better food and clothes obtainable by the wage-earners. But visits to the hospital constitute, after all, only a *claim* to sickness and workers earning good wages are less stimulated to claim sickness than are workers in the same "marginal" state of health earning less wages.

(2) Though a medical certificate is usually required and also a visit to the claimant, the *granting* of the claim may vary according to the standard adopted by the administration. One union studied by the writer, for instance, suddenly changed its practice and refused to take "neurasthenia" as a disease justifying benefits.

(3) The *type of member* may change. In technical language the "goodness" of the "lives" may differ.

Married women, for instance, are subject to a high rate of sickness, and if a women's labor union consists more of married women at one time than another, benefits will rise without measuring a fall in working capacity.

Sources of Record

According to the 23rd Report of the Commissioner of Labor, page 389, there were in 1908 at least 429 establishment funds in the United States with a membership of 322,246 paying temporary disability benefits. In the case of 57 of these establishment funds disability from accident only was considered, but in the remaining 372 funds there seems a wide and profitable field for the investigator.

Labor unions in England and Germany nearly all pay a definite weekly benefit to their members for a certain definite period, when they have been sick more than a few days. In the United States the practice is not so common, but several national unions and many more local unions have published figures of the temporary disability benefits paid out. In 1914 the following national and international labor unions paid out over $50,000 each in this benefit: the Cigarmakers, the Ironmolders, Carpenters, Boot and Shoe Workers, Hotel and Restaurant Employees, Plumbers and Steamfitters, Western Federation of Miners, Barbers, Street Railway Employees, Bakers. The unions are placed in order of the amounts paid—highest first.[1]

3. OCCUPATIONAL MORTALITY RATES

The only detailed attempt to trace the healthfulness of occupations as such through statistics of mortality occurs in Vol. XIV of the United States Report on the conditions

[1] The British State Insurance scheme has been disappointing for our purpose, but valuable Leipzig Sick Fund Statistics (under the German scheme) were published in 1910.

of woman and child wage-earners.[1] Dr. Perry, who was responsible for this investigation, compared the death-rate among women who worked in textile mills against the death-rate of women who did not work in factories, both occupied and unoccupied being drawn from the same wealth class, the same locality, and falling into the same age-group. In this way the main causes of ambiguity were eliminated.

The comparative mortality rates for different occupations are published by several governments, notably in the decennial supplement to the British Registrar General's Report. The difficulties of interpretation are, however, almost insuperable. The different incomes and habits of the several occupations, their different age-constitution, the difficulty of assigning to any one occupation those who have retired from work or those who have changed their work, create too many ambiguities.

In the British report the causes of death are stated, and it is possible, after subtracting accidents and suicides, to ascertain what occupations are most liable to lead to specific fatal diseases in comparison to other fatal diseases. But until physiologists can tell us more of the effects of accumulated fatigue in producing specific diseases, this comparison, though clear of certain ambiguities, seems of little significance.

4. LABOR TURNOVER

The labor turnover is the ebb and flow of employees into and from any factory's employment. It is often studied under the name labor recruitment, labor replacement, labor renewal, labor wastage, or hiring and firing, though the latter term disregards the fact that employees most often leave of their own accord without dismissal from the man-

[1] Recently the Occupational Mortality Experience of the Metropolitan Life Insurance Co. in 1911-1913 collected by Louis Dublin has been published as *Bulletin 207 of the U. S. Bureau of Labor Statistics.*

agement. The subject is of great importance in estimating the expenses of production. A high turnover means, among other costs, the perpetual training of new workers, and the accidents, spoiled materials and tools consequent on the introduction of new workers; idleness of equipment while new workers are engaged to replace the old and all the disorganization consequent on changes.

For the investigator into fatigue the importance of turnover arises mainly in checking, and also in completing, the lesson of all the other measures of working capacity. So far investigators have for the sake of statistical accuracy been recommended only to compare the records at different times of the *same* workers; workers that drop out of the factory between the several periods studied are therefore not counted—but it is just these workers that have most likely been the heaviest sufferers from fatigue.

The ultimate measure of Industrial Fatigue is the average productiveness of industrial workers each and all over their entire lives; it is not merely the productiveness over short periods of the select few that can be constant. To take an extreme view, employees that are constant might be regarded as survivors and their records only as supplying the measure of the "fittest," while the change in working capacity of those whom overwork has sent "to the scrap-heap" escapes measurement altogether. The British Health of Munition Workers Committee in their Report (p. 75) complain:

> Again and again investigators have reported to the Committee that the data at their disposal for examining output over sufficiently long periods are curtailed by the disappearance of a certain proportion of the operatives.
>
> Thus Dr. Vernon, reporting on the output of lathe operators at a munition factory, states:
>
> "The strongest women available were picked out for the work, but many of them could not stand it for more than a

few weeks. Of the 95 operatives of whose history I possess an adequate record, 22 gave up after four weeks or less, and 11 more after 10 weeks or less, but I have no information as to the cause of their retirement."

The Committee have also ascertained in reference to a munition factory employing between seven and eight thousand males under the age of 21 years, that every three months 25 per cent of this total disappear.

Captain Greenwood further reports that at another factory, out of one group of 287 girls at work in the week ending 24th January, 1916, 30 had disappeared by 3rd April, a period of 11 weeks; out of another group of 77, 14 had disappeared in the same period; out of another group of 37, 12 had disappeared; and out of another 100, 16.

Since "the whole of the operatives providing the data were, so far as could be ascertained, strict piece workers, who had, prior to the periods studied, sufficient experience to have attained their normal level of productive power," even after due allowance has been made for the nomadic habits of workers, the Committee consider that such figures indicate a serious and undue wastage of skilled labour. Steps are being taken to investigate more fully the extent and causation of this wastage.

What is required is some information as to the reasons for retirement, more particularly in the case of resignations or disappearances and as to the subsequent career of the retired employee. Retirement may be due just to discontent and discomfort and the chance of bettering one's position, or it may be sickness or nervous breakdown—a definite loss in working capacity. The only factory I have found that was able to obtain reasons for every case of retirement — and over 13,000 retirements took place in the year studied—showed that roughly 40 per cent of the workers left because "dissatisfied with factory." Yet this factory is famous for its high wages and short working day.

It is also important to find out how long the worker has

been in the factory before he left; the average length of "tenure" and the nature of the deviations from this average.

If the factory keeps no record of these facts, investigators—especially if they are women—might well pay a visit to the homes of the retired workers, who still live in the district, and make inquiry there. This course was pursued under the Committee quoted above and very significant information was elicited as to the part played by sickness, nervous exhaustion and the physical discomfort experienced by "misfits". High turnovers could undoubtedly be reduced if the management paid more attention to the sympathetic assignment of work suitable to particular types of workers. The writer has often found that a large proportion of girls leave a factory in their very first week of employment simply through discouragement.

The turnover rate is enumerable in any given period as the percentage of workers newly hired or leaving *based on the average number required to operate the whole plant.* On this basis, cotton mills report a turnover of 67 per cent a year, paper manufacturers 68 per cent a year, the metal-working industry 100 per cent, and so on.[1]

This measure of turnover assumes that the factory studied is static, neither increasing nor decreasing as regards numbers employed; that the new hirings are all to replace employees who have left, and that men quitting will all be replaced. If, however, additional workers are continually hired because the factory is growing or men are fired because the factory is partially shutting down, then a more adaptable measure is required, especially if the basic period is as long as a year, when great changes in number may have occurred and great changes in the requirement of the plant. Suppose that a given factory is decreasing in num-

[1] Mr. Ordway Tead and Mr. Richard B. Gregg have published several analytical studies in this field.

bers in one year from 500 to 450 and the number of men newly hired in that year is 90 while the men that have left (including probably some of those newly hired) is 140, then the rough measure of turnover would be either 140 or 90 (according to whether hirings or retirements form the numerator) divided by $\frac{500+450}{2}$ (the number required to operate the plant on the average throughout the year). It is obvious, however, that only 90 men are actually turned over; the remaining 50 are definitely turned *down*. Hence where the factory is *decreasing* in number the "hirings" seem the better numerator; but conversely, where a factory is *increasing*, the "firings" and retirements generally should be taken as the measure.

Both cases are brought conveniently and significantly under one head if the labor turnover be defined as the number of employees leaving a factory whom the management finds it necessary to replace, and the turnover rate as the proportion of such vacancies that were filled to the total number of men employed.

The amount of the turnover is equivalent to the number of employees leaving, therefore, only when the number newly hired is greater than this number leaving; when more men leave than are hired, the excess leavings are, *ipso facto*, *not replaced*. The turnover can thus be calculated by taking the lesser of the two numbers—the number hired or the number leaving; for the excess between the two must always be rejected.

Now, the turnover rate may be reckoned for any period—say the week, the month or the year. But it is important to notice that weekly turnover rates cannot be equated to monthly rates simply by adding the turnover for each week in the month; nor yet can monthly rates be equated to yearly by a simple addition of the twelve months. An ex-

ample will make this clear. Suppose in a month of four weeks that in the

1st	week	10	men	leave	and	13	men	are	hired	Turnover	10
2nd	"	15	"	"	"	11	"	"	"	"	11
3rd	"	12	"	"	"	17	"	"	"	"	12
4th	"	8	"	"	"	8	"	"	"	"	8
Total		45	"	"	"	49	"	"	"	Total	41

Then the total of the turnovers of the four weeks during the month is 41; but if we add all who had left and all who were hired during the month as a whole we find the lesser of the two figures to be 45.

In fact, the addition of the turnover for all the parts of any period will always come out less than the turnover for the whole period, for the reason, briefly stated, that a more frequently calculated rejection takes place of the excesses between hirings and leavings. This does not mean that one period of calculation is not as sound as another, but simply that the turnover rates per week or per month or per year cannot be compared by simply multiplying (or dividing) by four or twelve, as the case may be.

Similarly, the turnover of all the different departments of a factory added together will not produce the same figure as the turnover reckoned over the factory as a whole. In fact, the total of the parts will always be less.

Employers have been waking up to the importance of the Labor Turnover, and have been ready to consider schemes for investigation. As to the facts disclosed, a paper read by Mr. Magnus Alexander before the Employment Managers' Conference at Philadelphia in 1917[1] yields the most substantial information.

Mr. Alexander bases his rate not on the total number employed, but on the actual net increase in numbers em-

[1] *Bulletin of the United States Bureau of Labor Statistics*, no. 227.

ployed. For instance, he speaks of 42,751 people having to "be engaged during the year in order to increase the working force by only 6,697. In other words, about six and one-third times as many people had to be engaged during the year as constituted the permanent increase of the force at the end of that period."

This method of calculating turnover has the advantage of making proper allowance for a factory's change in size. When using the total number employed as a basis, it is plainly unfair to compare the rate at a factory which is increasing the number of its employees, and under the necessity of trying out new hands, with the rate at a factory which is regularly dismissing its hands and is able to dismiss those least satisfactory.

On the other hand, Mr. Alexander's rate can by nature only apply to the factory or group of factories that is increasing in size, and it will discriminate almost as unfairly as the rate per total employed against factories increasing faster than others, since such factories have to seek their new employees further afield and in less satisfactory quarters.

A labor-turnover rate that will measure fairly the attractiveness or healthfulness in any factory whatever, must take into consideration *both* the total number employed and the actual current changes in that number. A clever device for this purpose is to use as denominator the number employed at the end instead of in the middle of the period covered, which will automatically lower the ratio for factories increasing in size, and increase it for factories diminishing in size. However, the wisest course is to state the facts, *i. e.* the absolute amount of the turnover, the number employed on the average and the changes in that number during the period studied, and to leave the reader to draw his own comparisons.

PART III

THE MEASUREMENT OF INDUSTRIAL ACTIVITY AND CONDITIONS

CHAPTER IX

The Sphere of Deliberate Determination

The connection between length and intensity of activity and working capacity is obviously of the utmost significance to industrial organization and management. Question after question that every thinking factory worker or factory owner or factory inspector must have asked himself, can be answered satisfactorily only by a scientific study of activity as a factor in diminishing working capacity.

First of all come the questions connected with hours of labor, and the "speeding up" of the factory — questions directly linked up with length and intensity of activity, the prime cause of fatigue.

Factory managers, within limits, are able to plan and *vary* the total duration of activity within their factory and also the distribution of activity. They can settle how long work is to last for each day and each week and also how far this work is, so to speak, to be taken at one gulp, or dispersed by the introduction of rests of all kinds. The study of the effect of variations in length of activity is mapped out in Chapters X and XII.

Within limits, also, managers are able to plan the speed at which the work is to be performed and the amount of

work of any one kind, *i. e.* the "load," to be carried by each individual. The study of the effects of variations in intensity of activity is mapped out in Chapters XI and XII.

Obviously it is useless to study the effect of different lengths of activity while neglecting the possibility that a greater "intensity" in speed and load may counteract any shortening of activity. In America especially it is only too probable that the shortening of hours of labor has only half solved the problem of fatigue. However difficult it may be, we must make some attempt to study the effect on working capacity of the "intensity" of the work.

How far the manager's plan of activity is carried out depends to some extent on the workers employed. The worker has usually greater freedom in the matter of intensity than he has in varying his length of activity.

Whatever the length and speed of activity and whatever the load "set" the worker may yet "respond" by any variety of intensity he chooses. In most circumstances he may for any given load of work adopt what speed he chooses and for any given speed of work he may choose what load he will carry at any given time.

If it is the investigator himself who is recording the observation, he may notice occurrences in the course of activity that the official schedule may not have contemplated. The actual duration, distribution, speed and load he may find to differ materially from schedule—or again he may not. In fact, the investigator might use to great advantage the last column of the output recording-table shown on page 47, and note down occurrences under the following aspects of industrial activity:

(1) The Voluntary Wastage of Time, if any.

The number and duration of rests taken and their nature, *e. g.* idling, sleeping, stretching, *etc.*; amount of talking or singing, eating, or leaving room.

(2) The Results of Involuntary Wastage on Intensity of Activity.

How far the workers get "incited" or "excited" (see above, page 18) or spurt after an unanticipated involuntary stoppage or before one that is anticipated.

(3) Remarks passed by the workers which would throw light on their subjective feelings of fatigue (see page 16).

(4) When and for how long a stretch the workers seem able to fall into a rhythm.

A second category of questions to be solved by the factory manager and only soluble through fatigue studies is that of suiting work and workers. What are the different mental and bodily requirements of different types of work and what types of workers, what sex, age, race, should be selected for each type of work?

The answer to these questions of organization in the strict meaning of the word is obtainable through the twofold investigation of the effect of the factor "Type of Worker" and of the effect of the factor "Nature of Work" in influencing the onset of fatigue, in either predisposing or postponing a diminution of working capacity after activity. The method of conducting such studies is described in Chapters XV and XVI.

This category of questions is inseparably connected with the process of learning considered in Chapter XIII. In their Interim Report (page 77) the British Health of Munition Workers Committee pass the following telling criticism on factory management:

The Committee think it strange that while soldiers are sedulously instructed both in drill movements, which are indirectly, and in rifle and bayonet exercises, which are directly of value to them in carrying out their duties in the field, munition workers, not less important contributors to our national defence, have to depend upon casual and haphazard information, or may be referred to technical schools which, however excellent, can

no more replace factory instruction than can drilling in the park training in the field; and have noted that, though in the athletic world instructors exist to teach boxers how to balance themselves and use their arms, and cricket professionals are constantly at work improving the efficiency of batsmen and bowlers, and coaches are a necessity to teach a boat's crew collectively and individually how and when to move their bodies and hands, yet in the industrial world the value of teaching operatives how to earn their livelihood is hardly yet recognized. In America much has recently been done, in association with what is known as " scientific management " to eliminate useless movements and lessen physical effort, but, somewhat unfortunately, the subject has got wrapped up with " time studies " used for fixing piece rates, and there is, in consequence, a tendency for it to be looked on with disfavour by wage-earners, while the real value of teaching is being lost sight of. The Committee feel no doubt that just as the athlete obtains further incentive to skill by seeking information as to his faults from a trained teacher, so should operatives be able to turn for instruction as to wasteful and non-productive practices unconsciously developed, and as to methods of improving their work with less effort, and that such teachers would be able to give useful advice to the management as to the most suitable speed for running machinery and as to the best moment to choose for rest pauses. The ideal foreman should be such a teacher, but foremen who consider such duties part of their daily work are seldom found.

The method of ascertaining what instruction should be given, is suggested by the same committee in an earlier passage:

It will also be important for proper management to take account of the output of particular individuals. This in many factory processes is easily possible, and when it has been done the results have shown surprising variations of individual output which are independent of personal willingness and industry,

and have generally been quite unsuspected by the workers and their supervisors before the test was made. Information so gained is valuable. . . . Good individual output is often the result of escape from fatigue by conscious or unconscious adoption of particular habits of manipulation or of rhythm. Its discovery allows the propagation of good method among the other workers.

Finally, a third category of questions soluble by the factory management, with the help of fatigue studies, are those of factory conditions: the ventilation of work rooms, the provision of meals, and the introduction of nightwork and overtime, which draws attention in turn to the danger of reversing workers' habits, of working in artificial light, and of securing insufficient sleep.

The importance of factory conditions as influencing the working capacity is now so well recognized that further recommendation is unnecessary; the only uncertainty lies in the method of measuring variations in these conditions numerically, and associating them with variations in working capacity. Such attempts to evaluate and correlate the methods employed will be found briefly summarized in Chapter XIV.

Thus the measurement of industrial activity and conditions of life generally involves the same principles as the measurement of working capacity described in Part II. It is possible to guage the exact effect of length of activity because the period of labor can not only express activity without ambiguity but can be minutely adjusted to any quantity of hours or minutes. Other factors especially of the "social," "habits" and "point of view" type are not subject to enumerable variations—*e. g.* we cannot say positively that one man is twice as patriotic as another—and it is this fact that limits statistical investigation to the questions raised in this chapter, and studied in the chapters that follow.

PART IV

THE DEMONSTRATION OF FATIGUE

Correlation of Variations in Activity with Associated Variations in Working Capacity

The investigator who uses the actual events of industrial life as his data is seldom able to arrange the conditions to suit his own plans. He cannot, like the experimenter in the laboratory, pick and choose each one of the factors likely to influence his results. Sometimes where the investigator is himself the manager of a factory, like Dr. Abbé at the Zeiss Optical Works, or has influence with the management, he may be able to vary a few of the conditions. Thus Abbé deliberately reduced the hours of work from nine to eight per day while Frederick Taylor at the Bethlehem Steel Works was able to measure the effect of rest-pauses "empirically" by continually varying the proportion of rest taken by the worker.

For practical purposes, *i. e.* where the manufacturer really wishes to learn what are the hours of work yielding maximum efficiency, such empirical measurement is by far the most reliable. A regular table of "co-variations" could be made out showing in one column the various amounts of work administered and opposite each in the next column the varying effect on working capacity. The hope fostered by Dr. Abbé's and Dr. Taylor's work has not, however, been realized. When manufacturers for any reason do change their hours no accurate observations are made of the result on working capacity; and scientific man-

agement, though it continues to propound the vast possibilities of increasing personal efficiency has turned to the organization of the material equipment or else to pure speeding-up, rather than to a scientific study of the human factor.

The opportunities offered to the investigator who is not doing more than observing the effect of predetermined variations of industrial activity are twofold.

The most important chance for comparisons occurs where the length or intensity in any given factory or district has been changed and the resultant working capacity in the period before and after can be *contrasted*. Particularly in the same factory contrasts are possible where, owing to strikes or trade conditions, there is short-time or overtime, or owing to a definite reorganization, (1) the total length of hours has been reduced or increased, or (2) rest-periods have been introduced or cut out and the distribution of hours altered, or (3) activity generally has been intensified or slackened.

The second type of opportunity, though usually significant only as to the distribution of activity, is more frequent, and may be used either alone or in conjunction with a contrastive study.

It occurs where observations can be made during *consecutive* divisions throughout some definite or continuous working period.[1]

The results are often spoken of familiarly as the *work-curve* for the given period; the height of the consecutive observations being plotted as connected points on a curve. Thus if the output of four consecutive hours is 25, 32, 30 and 24, the curve will rise suddenly and then fall gradually, in the form of a saddleback. Curves may be of all conceivable shapes, including a perfectly straight line!

[1] See the writer's paper in "Public Health Reports" issued by the *U. S. Public Health Service*, March 15, 1918, reprint no. 458.

CHAPTER X

Contrasted Variations in Length of Activity

The effect on working capacity of variations in total *duration* of activity can be found by contrasting two different working schedules, *e. g.* an eight-hour day against a ten-hour day. Ernst Abbé's study was of such a type; after becoming manager of the Carl Zeiss Optical Works in Jena he reduced, in 1900, the working day from nine to eight hours. By the most careful computation of the output and use of power for four weeks separately under the nine-hour schedule and for another four weeks separately under the eight-hour schedule he found the total output and power-consumption per day slightly higher with the shorter hours, and thus the *hourly* efficiency was about 16 per cent higher.

Another duration-contrasting study was made at the Engis Chemical Works near Liège. The company had a sick benefit fund which was constantly depleted, and the manager became alarmed. He tried the effect of introducing three shifts of eight hours. The output equaled the previous output of ten hours' work, and the earnings, all piecework, equaled the previous earnings. The increase of output and wages per hour was about 33 per cent. The sick benefit accounts showed that under the old system expenditure had exceeded receipts; while under the new, receipts tended to exceed expenditure and that progressively.

Quite recently the British Health of Munition Workers Committee published two Memoranda (No. 12 and No. 18) entirely devoted to contrasting the effects of changing total hours. We may give in full one of the tables compiled by Dr. H. M. Vernon who is responsible for this very lucid presentation of an able investigation.

TWENTY-SEVEN MEN SIZING FUZE BODIES

Statistical period	Average hours of actual work	Average (relative) hourly output	Hours × output
6 weeks preceding Christmas... (November 8—December 19)	61.5	100	6,150
2 weeks at Christmas ..... (December 20—January 2)	38.3	89	
6 weeks after Christmas ..... (January 3—February 13)	51.1	109	5,570
8 weeks later ..... (February 21—April 16)	55.4	122	6,759
2 weeks at Easter ..... (April 17—April 30)	41.0	112	
3 weeks later ..... (May 1—May 21)	56.2	124	6,969

Dr. Stanley Kent, too, in his Second Report to the British Home Office has contrasted output records under different durations of activity to supplement his physiological tests. Contrasting the rate of output (1) when four spells are worked, (2) when overtime is dropped, and (3) when both overtime and the usual English spell before breakfast is dropped, he found that sometimes the total day's output was actually greater when the day's work lasted ten hours than when its duration was twelve hours.

Similar contrasts in duration of activity will be found scattered throughout industrial literature. Particularly famous are the investigations at Mather and Platt's Ironworks, Salford, England, in 1894, and at British Arsenals subsequently.

The effect on working capacity of different *distributions* of hours of activity can be gauged by contrasting data under different schemes of distribution, *e. g.* output under a frequently interrupted working day against output under long uninterrupted spells.

It is studies of this type that scientific management may claim credit for initiating. Frederick Taylor in his "Principles of Scientific Management" has made famous the

case of the "ox-like" Pennsylvania Dutchman at the Bethlehem Steel Works who was able to increase his earnings from $1.15 to $1.85 by obeying instructions to take rest 57 per cent of his time. A similar "distribution-contrast" is recounted by Mr. Gilbreth in his recent "Fatigue Study." Some girls engaged in folding handkerchiefs by hand were told to pause every sixth minute and at the end of each hour to walk and talk for six consecutive minutes; their posture was also varied, sitting and standing being enjoined alternately with optional periods. As a result an output three times the amount of the previous best work is reported.

Contrasts in the effect of different distributions of activity may be drawn also where Sundays are worked some weeks and not on others. At a rifle cartridge-making factory the writer compared the output of the full working days of the week after a Sunday holiday with the corresponding output in weeks before and after when Sunday was worked in full. The result showed a substantially higher rate per machine per hour when the previous Sunday had not been a working day.

The contrast before and after a change in duration or distribution of activity is more liable to ambiguities than consecutive studies owing to the fact that when contrasts are made between different and sometimes distant periods other factors besides length and intensity of activity are liable to have altered, or may even have been consciously altered, with the change of hours of work.

In one munition factory of over a thousand hands a certain increase had been made in the number of hours worked. Six months later, after searching through all the records kept by the firm, the writer found only eight cases where the same worker was working on the same operation as he had been before the change. To attribute all differences in results to differences in activity becomes, therefore, scientifically speaking, more difficult, if not impossible.

CHAPTER XI

Contrasted Variations in Intensity of Activity

"Practically, the greatest need felt in an establishment wishing to start a rate-fixing department is the lack of data as to the proper rate of speed at which work should be done.

"There are hundreds of operations which are common to most large establishments; yet each concern studies the speed problem for itself, and days of labor are wasted in what should be settled once for all, and recorded in a form which is available to all manufacturers.

"What is needed is a hand-book on the speed with which work can be done, similar to the elementary engineering handbooks. And the writer ventures to predict that such a book will before long be forthcoming. Such a book should describe the best method of making, recording, tabulating, and indexing time observations, since much time and effort are wasted by the adoption of inferior methods."

In spite of these words of F. W. Taylor, the effect on working capacity of different speeds and different loads has only rarely been made the subject of comparisons. This neglect of investigation is due probably to the fact that the measure of intensity is that same rate of output that is the most direct and most frequent measure of working capacity. Increased speed and increased load *imply* in themselves increased output, and the investigation would seem merely to move in a circle.

If the accident rate and the proportion of spoiled work and of sickness be employed as a measure, however, it will soon be observable whether a high rate of output is the re-

sult of an increased working capacity or of the same working capacity merely speeded up. The driving of a man beyond his powers, which ultimately must result in sickness, is the very condition to make a man flurried and inexact in his movements and thus to cause accidents and spoiled work.

To the statistician dealing in exact figures the real difficulty occurs at a different point. It lies not in the measuring of working capacity, but in the measuring of intensity. How can he "enumerate" what a man's intensity was, in performing his work?

Here, again, by its stereotyping of conditions, modern factory industry comes to the aid of the investigator. Just as a given number of hours arranged in a given way are planned out or "set" for work beforehand, so a certain speed or load now is often planned or "set" as the scheduled working intensity. In both cases, it is true, you may bring a horse to water but you cannot make him drink. The periods set for work are not necessarily filled in; the set speed or load is not necessarily achieved.

The further question is therefore necessary, what is the strength of the incentive, stimulus or agency through which the workman is to achieve the speed "set"? A man's intensity of work is likely to be higher the higher the intensity "set" and the stronger and easier the stimulus or agency in reaching it. The statistician must therefore be able to reckon numerically not merely the height of schedule intensity but also the force of the agency. When that is possible the divergence of set intensity and the actual working capacity will be measurable, and measurable numerically.

In industry to-day four different types of agency can be distinguished:

1. The "mechanical" stimulus produced purely by an alteration or adjustment in mechanical appliances.

2. The emotional stimulus acting on the human instincts and appealing to the feelings and imagination.

3. The economic stimulus acting quite particularly on the human intelligence and appealing mainly to the desire for wealth. Strictly speaking, it is only these last two stimuli that can be called "incentives". We shall consider them together under that title.

4. The reflex agent acting on the lower nerve centers and bringing into play the purely animal structure of the human body. In motor activity, *rhythm* is by far the most important agent.

I. THE MECHANICAL STIMULUS

When a worker instead of having to watch two machines is set to watch three, his *load* may be said to increase 50 per cent, and it is an important subject for investigation how far the working capacity can meet the increased strain and produce a full 50 per cent increase in output without a disproportionate increase in sickness, spoiled work and accidents. Very probably the output *per machine* will fall as the number of machines to be watched by each individual increases. It would form a useful subject for investigation to find in the textile industry, for instance, how much the output per spinning frame or weaving loom decreased as the number of frames or looms per operative was increased.

Where the speed of the machine is the main determinant of the intensity of work, the obvious mechanical device for increasing production is to *speed up the machine itself*. In making rifle cartridge cases on semi-automatic machines, while at each revolution of the crank the tool comes into operation on a case, the number of revolutions is not predordained. Thus, in piercing the cartridge-case on the same type of machine one firm was found to speed the machine at 84 revolutions a minute, another at 120 and a third at

130; again in heading the cartridge-case the three firms speeded the same machine at 84, 75, and 100.

How far the speeding-up of the machine itself effects a similar speeding-up of the worker depends naturally on how entirely the machine determines the pace. In the rifle cartridge making processes cited above, the material was fed into the machine on a long slide acting as a sort of reservoir; in other processes each cartridge was placed in holes at the circumference of a turning dial. The worker in both cases was quite free to omit to keep the machine fed; so that it does not follow that the output is exactly equivalent to the number of the crank's revolutions per minute multiplied by the number of minutes worked.

It would be interesting, indeed, to be able to compare the actual product per minute with the speed set. Very possibly if the speed were set too high, the workers on the dial-fed machine would definitely lose the habit of filling every hole as it passed before them, and even the workers on the slide-fed machine might let the reservoirs run out. Unfortunately, however, factories usually do not keep the time the machines actually ran; they only compute a percentage efficiency, which is a comparison of the *actual* output with the output that was *possible* if each machine were running for the whole time that the factory was at work; the frequent stoppages due to breakdowns of the machine or to lack of materials are not considered. However, even this rough indication of efficiency shows when compared to the machine speed that there may be a limit to the "incentiveness" of mechanical speeding.

Comparing similar processes for two different factories both engaged in making rifle cartridges on semi-automatic machines it was found that in piercing the cartridge-case a machine speed of 130 revolutions per minute in the first factory produced an actual "efficiency" of 34 per cent,

while with a speed of 84 revolutions the efficiency was 47 per cent. A higher "efficiency" did not accompany a lower machine speed in all the processes nor yet does this "efficiency" show anything more than the proportion of actual and possible output—if machines ran constantly all day. Yet it is sign enough of human limits to speeding.

2. THE HUMAN INCENTIVES

The divergence of actual working capacity from "set" speed is next most easily enumerated where the management has instituted a definite "task" for the workers to attain in some given time and has devised a strong "economic" incentive to reach the task either by the payment of a bonus when the task is accomplished on time or by payment of progressive (or "differential") piece wages. By progressive piece wage is meant any system by which the more output a man produces in a given time the greater is his *rate of pay per unit.*

Under such a system, investigation might possibly disclose that if the task is set too high, or the progression is too steep the desperate effort to "make good" will in the end diminish working capacity, the output may be less than it would have been without a differential wage or set task, and accidents, spoiled work, and sickness will rise out of all proportion.

Variations in the incentives provided by discipline, or the appeal to sporting or patriotic emotions are not measurable numerically. Variations in the natural stimulus of interest in the work itself, or, what is more common in the factory, keenness in the *achievement* of some work, are also not enumerable.

This does not mean that the investigator should neglect the influence of social conditions, moral outlook, and mental disposition, nor yet the consequence of incentives devised

artificially by means of competitions and prizes, or by bedecking the factory with flags; nor yet neglect the potency of threats to fine or to dismiss on the part of the foremen. All these factors, though their force cannot be reckoned numerically, yet must be allowed for in estimating intensity of work. A glimpse of the power of this kind of stimulus is afforded when a factory is working under stress to fulfil, "rush" orders.

"Rushes" are part of the normal existence of most factory wage-paying or costing offices, and the typists and clerks usually respond by means of "spurts." Spurts differ from incitement or reflex stimulation in being a thoroughly conscious process consciously applied. They are described by Weber [1] as effecting a short, sudden increase in output and often coming into action as soon as fatigue is subjectively noticeable and the individual determines nevertheless not to allow his efforts to flag. Sudden increases in the speed of output were certainly registered in an observation the writer made of the time required for a typist to write letters from dictaphone records. The average speed was roughly two lines per minute, but in the last quarter of an hour in the evening, when correspondence had to be despatched before closing time, the speed would frequently reach 4 lines, and on one occasion attained 5.15, per minute; the average for this last quarter of an hour and the half-hour that preceded it was 3.83 and 2.83 lines per minute respectively if tea had been taken previously, 2.83 and 2.16 respectively if no tea had been taken. The joint effect of material "stimulants" and emotional "stimuli" is obviously powerful.

The limit to the possible duration of the effect of an emotional stimulus is evidenced by an observation of the girls assembling chains on a machine. One of the operators

[1] See page 18 above.

had obtained leave to go home after tea at 5:45, but presumably not wishing to fall behind in her work was seen to be putting on a spurt at about 4:30, when she completed a chain in six and one-half minutes instead of her average of 7.6 minutes. After this the minutes in which successive chains were finished were 6¾, 7, 7¼, 8½, 7¼, 10, 7½. The "spurt" failed after the first four chains (completed under 7 minutes on the average) and speed is reduced on the average to 8½ minutes per chain.

3. THE INFLUENCE OF RHYTHM

The great importance of contrasting working capacity of differently set loads and speeds arises from the phenomenon of rhythm. *One speed if it is in consonance with the rhythm of the workers may well produce double or treble what a speed only a little too fast or a little too slow may produce.* It is well worth the while of manufacturers, therefore, to discover empirically what is the "eurhythmic" speed and load.

Rhythm may be defined as the regular and frequent repetition of a group of differentiated motions and pauses. If the rhythm of the operation is suited in speed and load to the human rhythms corresponding to the trot, gallop or canter of the horse (which are probably dependent on the physiological processes such as respiration, the beating of the pulse, metabolism, and the succession of nervous strains and reliefs), there will result a greater ease and co-ordination of movement, a saving of mental responsibility and worry, and a pleasurable feeling "all over." In short, rhythm is a great economizer; it permits a greater activity and a smaller effort.

To measure how far any given industrial operation is liable to rhythm, in so far as it is repeated frequently and regularly, the investigator must make a microscopic

time study. One or more motions within the operation should be selected and the interval timed between the reappearance of the same motions in each successive repetition of the group of motions or "operation". If the interval is so short that the mere reading off or stopping of the watch would upset calculations, then by holding the watch close to the ear the investigator may count the number of intervening "ticks". The shorter the intervals and the less they deviate in length one from another the more the chance of rhythmicizing the operation. By its continual subdivision of labor and by the standardization imposed by the machine, modern industry probably presents a continually increasing proportion of operations amenable to rhythm.

Feeding of machines and other semi-automatic work is the most regularly and frequently repeated type of operation, particularly if there should be some sort of "cue" to start off each repetition of the operation like a signal. Above were described certain processes in the making of rifle cartridge-cases, pages 108 and 109. Some of the semi-automatic machines used are fed by a revolving dial with holes on its circumference, in which the worker places the cartridges. It is likely that as each empty hole revolves past the operator it proffers its emptiness as an obvious receptacle for a cartridge-case and automatically the operator will drop one in.

As mentioned above, the Health of Munition Workers Committee, in Memorandum 7, take over the medical use of the term rhythm to denote simply a regularly repeated alternation of two occurrences, such as work and rest. As applicable in industry the word, however, may be used for something far more positive and far more complicated of which frequent and regular repetition is only the basis. The "differentiation" that may take place among the motions that are grouped is of many kinds. This will soon be perceived

by a watchful investigator prepared to make a "motion study" of any given operation in the factory. Even where the operation is rhythmic, in so far as it is regularly and frequently repeated, the desired economy of working will not result unless the motions composing the operation are grouped and differentiated to suit human exigencies, especially the pace of the human machine. Rhythmically significant differentiations between each motion within an operation may relate

(1) To the comparative stress or emphasis laid on each motion

(2) To the different direction or "path" of each motion

(3) To the comparative rapidity of each motion. Obtained by the ratio $\frac{\text{Distance covered}}{\text{Time spent}}$

(4) To the part of the body, "the agency,"—right or left hand, foot, *etc.*,—performing the motion.

Where a group of men is working together each member may fit into and form part of a group rhythm like three men hammering at a stake. Each man, in fact, may be looked upon, like the various members of the human body, as a different "agent."

Music, like that of a band at the head of a regiment or in the ball-room, or even noise of any kind like that of factory machines or of hammering, often supplies the differentiation required between the motions it accompanies, by variations in tone, pitch, time or quality.

Investigation of the effect of rhythm as a stimulus to the working capacity in achieving intense activity may proceed along several lines.

Output may be contrasted in the same operation and with the same individuals when there is music played or singing

and when there is not; or when there is a cue offered or group work arranged and when there is not; or when attention is paid to the motions of the operations to get them regularly repeated and properly differentiated in stress, swing, rapidity and agency and when no attention is paid to this.

Conversely, the most capable workers may be observed and their motions analyzed and timed.

To supplement the ordinary "literary" description and timing of motions Mr. Frank Gilbreth, for instance, has devised a series of photographic appliances including the motion picture, exhibiting particularly the path and the rapidity of motions, and he claims to have found most definite laws in the relation between these two "differentiations."

It is likely that experienced workers will have arrived at a rhythmic *modus vivendi* which it will take the inexperienced hand years to pick up, just as in the medieval crafts it used to take seven years for the apprentice to become journeyman. It is to rhythm particularly that the demand of the British Health of Munition Workers Committee, quoted above,[1] applies; to avoid waste of time and effort learners should be definitely instructed in the art of mutually adjusting the pace of the human machine and the motions of an operation.

[1] See pp. 99 and 100.

CHAPTER XII

Consecutive Variations in Length and Intensity of Activity

Consecutive studies need not wait upon any change in the working schedule of the factory. Taking the working periods of any one factory or industrial district as they are, all the investigator need do is to divide up any whole period he may choose to study into consecutive part-periods and compare the variations in his data as between each consecutive part-period. In Chapter II a brief sketch was given of what was called the conformation of working life. This consisted in alternate working periods bounded by rests. These working periods were pointed out as the "spell" of continuous work, the working day and the working week bounded respectively by the interval, the night's rest and the week-end. Each working period forms with its respective rest period an industrial "cycle," or alternation of activity and relaxation which recurs over and over again in the life of the worker.

Each such industrial cycle may form the subject of a consecutive study. The week will be divisible naturally into the days of the week and the days into spells, and the variations in the data for each consecutive day and each consecutive spell will form the curve for week and for day.

When, however, the investigator wishes to secure a "curve" for the spell or at the other extreme a comparison of consecutive weeks or months over a long period, the periods he is to study must be chosen artificially.

The hours or any other division of a spell of continuous

work are not "given naturally." They are divisions created "*ad hoc*" by the investigator for his own purposes.

A similar artificial period foreign to industrial organization is the month and, generally speaking, the year. It is only when there is a substantial and regular vacation to mark the end of one "working" year and the start of another that the year can be called industrially a defined entity.

A series of divisional periods taken consecutively within a cycle will be called a cyclical sequence. A series of divisions within a period industrially undefined will be called a cumulative sequence.

The sequences most usually and most usefully studied are,

A. The sequence of hours throughout a spell. This is a recurrent cyclical sequence of artificially created divisions. The hour is adopted as the division only because of its obvious convenience.

B. The sequence of spells throughout the day. [A and B are usually studied together.]

C. The sequence of days throughout the week. [B and C are recurrent cyclical sequences of cycles.]

D. The sequence of weeks or months indefinitely. This is a cumulative sequence of cycles, or of artificial divisions, as the case may be.

The study of each kind of sequence has its special significance to industry and in each case also, the investigator must overcome certain technical difficulties.

(1) If the part-periods are not of equal duration the differences in time must be "allowed for." For instance, if one part-period is only half the length of all the others the number of units in the data must be *corrected* or pro-rated to the full part-period by being doubled. Usually if one part-period is less than half the length of the others, it is wisest to omit it.

(2) It is not always obvious at what point the part-periods shall be divided off. Thus the hour might run from 11 to 12 or from 11 : 30 to 12 : 30. This is the difficulty of *delimitation.*

I. SEQUENCE OF HOURS AND SPELLS THROUGHOUT DAY

Very many studies of this type are given in the first report of the Committee on Fatigue of the British Association for the Advancement of Science, 1915. One table employing output as a measure and another employing accidents, both drawn from familiar American sources may be reproduced, also a diagram showing how the accident curve can be plotted. Output, spoiled work and power can be plotted in the same way.

U. S. A. FEDERAL REPORT ON WOMAN AND CHILD WAGE-EARNERS [1]

Hours	*Output of Stamping-presses;*[2] *23 machines, 1 to 7 days each; day shift only*		*Spell*
7–8	37,631		
8–9	39,855		
9–10	40,201	40,047	Morning
10–11	40,316		
11–11 : 30	42,234 per hour		
12–1	39,156		
1–2	40,592		
2–3	41,258	40,678	Afternoon
3–4	40,373		
4–4 : 30	42,010 per hour		

ACCIDENTS. A MOTOR AND MANUFACTURING CO., DETROIT, MICH., JAN.—MAY, 1915

Hours of Work. 6 : 30—11 : 30; 12–5. Sat. till 11 : 30.

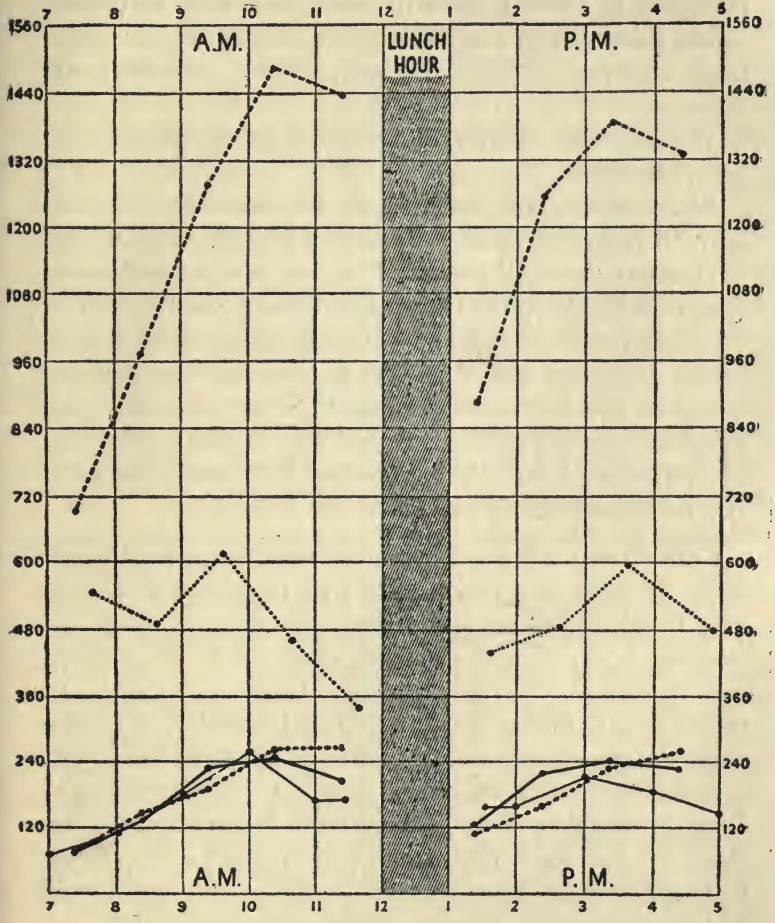
Hours of Day			*Hours of Day*		
6-30–7	58 per hour		12–1	25	
7–8	101		1–2	86	
8–9	86	89	2–3	101	97
9–10	99		3–4	119	
10–11	106		4–5	154	
11–11 : 30	88 per hour				

[1] *61st Congress, 2nd Session, Doc. 645,* vol. xi, p. 99.

[2] "The speed of these machines depends entirely upon the operator, since for each piece formed he must actuate a treadle."

[3] Afternoon figures include an average for Saturday.

DIAGRAM .—ACCIDENTS IN GENERAL MANUFACTURE.



Hourly tabulations of accidents during the day have been published by several states of the Union, such as Illinois, Massachusetts, Ohio and Wisconsin, and by several European countries, notably England, France, Belgium, and Germany.

The accident occurrences are often grouped under separate industries.

Some studies are confined to the sequence of spells only, disregarding hours. Professor Stanley Kent studied the comparative spell output of the four spells found in the long working day of the English munitions industry. Here there are usually two hours before breakfast (6-8 a. m.), then a four-hour spell 8:30-12:30, then an hour for dinner, then another four-hour spell 1:30–5:30, then tea, then the overtime spell 6-8 p. m. He found that the rate of output per hour was particularly low during the early two hours and during overtime.

Corrections: If the consecutive divisions cannot be of equal duration, *e. g.* if a spell of four hours and a half can only be divided conveniently into four separate hours and one-half hour, then the number observed in the unequal period, shorter or longer, must be rated for the sake of comparison to the duration of the equal periods. In the example chosen the amount of output or number of accidents in the half-hour must be doubled to produce the rate per hour. Even so capable a body as the British Departmental Committee on Accidents, whose report was issued in 1911, failed to notice the significance of the sequence of cotton trade accidents classified on page 63 above, owing to the fact that they did not allow for the meal-intervals in the figures for the hours 8-9, 12-1 and 1-2, though well aware of the usual Lancashire customs.

Delimitation: (1) The first stipulation in dividing-out the

working day must be that none of the part-periods should overlap the spells. I have found factories keeping consecutive hourly records, so bent on maintaining the hour as their measure that they would add the data from two odd half-hours occurring on either side of an interval. Thus, if hours worked were 8-12 : 30, 1 : 30-5, one period would be formed out of 12 to 12 : 30 and 1 : 30 to 2 and the observations before and after lunch inextricably mixed. If this is done the immediate effect of intervals will be entirely missed.

(2) As far as possible the divisions should completely cover the spell, but if at the beginning of each spell the factory takes considerable time to reach the state of constant preparedness stipulated above (see pp. 46-48) it may be wisest to start the hourly divisions a quarter of an hour or half an hour after the nominal scheduled commencement of work. Similarly if the workers quit their ordinary work early, the divisions should stop short of the scheduled stop-off.

(3) If records are likely to be timed at one part of the hour rather than another, extreme care is required in delimitation. It is probable, for instance, that the factory staff is more likely to report an accident as occurring at the full hour, *e. g.* 11 : 00 than either as at 11 : 01 or 10: 59, or even 11 : 10 or 10: 50. Similarly, 10: 30 will also in all likelihood be a popular figure.

Hence, in classifying accidents it may make a great difference to the curve whether the hour be taken as running from say 10: 00 to 10: 59 or 10: 01 to 11 : 00. In the latter case the numerous accidents reported as at 10 o'clock will be thrown back in the earlier hour; in the first case they will all be thrown forward into the later hour. A good deal of the apparent disagreement between hourly accident curves of different factories and states is attributable merely

to a difference in delimitation of the hours and a standard system is sorely needed for comparative purposes.

The writer would suggest 10:00 to 10:59 and 10:30 to 11:29 rather than 10:01 to 11:00 and 10:31 to 11:30 as the type, for the following reasons: even if the accident recorder is only timing occurrences roughly, he is not likely to "cook" the hour designations so much as that of the minute. Thus, if one accident really occurred at 10:55 and another at 11:05, the latter is more likely to be referred to 11:00 than the former, since in the former case it would involve a change of the hour designation from 10 to 11. The chief danger of inexactitude, therefore, occurs in the 10:01 to 10:10 accidents; they will almost certainly be registered as occurring at 10:00; and under the less satisfactory 10:01 to 11:00 and 9:01 to 10:00 type of delimitation they would then be classified back still further as occurring 9 to 10.

Significance. The practical value of studying hourly and spell sequence is to show how far, if at all, the element of unrelaxed activity gradually prevails in its effect on working capacity over the effect of the previous night's rest refreshed though it is by the meal intervals and any mid-spell breaks there may be. The data, for instance, of the third hour of the afternoon spell compared with the first hour of the morning spell will show the effect on working capacity of the unrelieved activity of the previous two hours, and of the activity of the whole morning spell relieved only by the noon lunch interval.

If the hint is not premature, investigators may be told that of all consecutive sequences the hourly sequence throughout the spell has hitherto been found to disclose by far the greatest variation in working capacity.

All kinds of influences seem to play on the human organism during this quite unrelaxed period. At the start there

is the warming-up to the work owing to loss of practice during rest, in the middle there are spurts of short duration, while towards the end an excitement seems often to prevail in anticipation of the coming interval for rest and food. The investigator should not be surprised, therefore, if the length of activity does not have an altogether single effect.

2. SEQUENCE OF DAYS THROUGHOUT WEEK

Professor Max Weber compared the output of individual weavers in a Westphalian factory on the different days of the week. Reducing the output per loom on the day of maximum output to 100 he presents his results as follows:

Output of	*Mon.*	*Tues.*	*Wed.*	*Thurs.*	*Fri.*	*Sat.*
(1) Minder of one or two looms	93.61	96.45	100	96.79	98.64	99.54
(2) Single loom minder	92.69	95.61	100	96.91	99·67	99.18

Many states of the Union, particularly Massachusetts, Ohio and Wisconsin, and some European countries, such as Belgium and Germany, furnish and have furnished accident figures for each day of the week—often grouped separately for different industries. An example may be given from Ohio, those industries being selected which are of the greatest importance in the State.

ACCIDENTS

OHIO: JAN. 1—JUNE 30, 1914, INDUSTRIAL COMMISSION, DEPT. OF INVESTIGATION. REPORT NO. 4

ALL ACCIDENTS INVOLVING DISABILITY FOR ONE DAY OR MORE

Day of Week	*Contracting (Building)*	*Metals*	*Coaches*	*Coal Mining*	*Pottery Glass*	*Total Industry*
Monday	321	2,268	229	204	177	4,632
Tuesday	269	2,224	214	194	199	4,522
Wednesday	288	2,187	223	165	171	4,388
Thursday	283	2,215	218	184	172	4,436
Friday	279	2,197	224	165	192	4,377

Correction: Where Saturday is a half-holiday it is wisest to omit the Saturday data from the sequence. To double or otherwise "rate" the number of units to the whole day would only yield a misleading picture, enhancing the differences due to the very fact of Saturday being only a half-day.

Delimitation: In tracing the sequences within weekly working cycles a difficulty may often arise owing to the form in which factory records are kept. In one munition factory the output records used by the writer were kept for the purpose of estimating piece-wages, and as payment was made on Wednesday, the week was reckoned from Tuesday to Tuesday. It was only by special request that he secured records for the natural calendar and working week.

Sometimes, where the work is performed in shifts, the calendar week is not identical with the working week. Here the working week must be delimited at the inversion of the shifts whether this occurs on Sunday or not. Inversion usually takes place every week, though sometimes every two weeks or month. On the two-shift system a rest of 24 hours is usually obtained then, by the old day shift missing one day and working the next night while the night shift misses a night and comes on next day. On the three-shift system a similar progressive rotation also results in a clear 24 hours' rest, *e. g.* the 6 a. m. to 2 p. m. shift will at the inversion start work, next day, at 2 p. m.

Significance: The practical value of studying the sequence of days throughout the weekly working cycle of activity and rest lies in this: to show how far, if at all, the element of activity gradually prevails in its effect on working capacity over the element of rest in the previous week-end, refreshed though it be by the night's rest at the end of each day.

The data, for instance, for Thursday compared with that

of Tuesday will show the effect on working capacity of the activity of Wednesday and Thursday relieved by no longer rests than that provided at night. Mondays compared with Saturdays, on the other hand, will show the effect of the long week-end rest.

3. CUMULATIVE SEQUENCE

In an English munition factory the output of rifle cartridges as a whole had increased fourfold during the course of a certain year. It was important to ask, however, how far this increase was due to the increasing proficiency of each individual girl composing the factory force and how far it was merely a matter of increasing the number of girls. Indeed, in view of the fact that on the outbreak of war the hours had been increased to 10 on dayshift and 11 on nightshift the output of individual girls might well have been expected to fall.

The firm had kept an output record for each individual girl for certain widely scattered weeks. Where it was possible the writer picked out the output record of all individuals who had remained on the same job throughout the period and, dividing by the actual number of hours worked, reduced the total output of each individual to a rate per hour. Equating the output of one group of operations in the first week selected to 100, the individual output was found to have increased 12 per cent in the fourth week after starting the investigation, but after that to have fallen to 4 per cent by the tenth and eleventh weeks. The fall is as expected, and the most probable explanation of the somewhat unexpected increase at the start was the growing experience of the operators. (See table, page 135.)

A study of continuous sequence was conducted by the writer at another munition factory in terms of lost time (or absence) percentages. At the outbreak of war the day-time

hours were increased from roughly nine a day to eleven a day and an eleven-hour nightshift introduced universally. Before the war the time lost through absences was about 6 per cent of total scheduled time; since the war, calculations made every quarter-day revealed a percentage rising gradualy in one department from 9.5 per cent in the fifth month of war to 12.5 per cent in the same month a year later, and in another department from 12.5 per cent to 16.5 per cent during the same year. Also an attempt was made to check this measure of working capacity of the absence percentage by comparing the measure of monthly accident rates per numbers employed in the same factory.

The practical importance of cumulative studies lies in disclosing "accumulated" fatigue — fatigue that is never wholly wiped out by rests and that ultimately must prevail to the full extent of invalidity and death.

4. CONTRAST OF SEQUENCES

The two modes of comparison, by contrast and consecutive, may be combined by contrasting the hourly, spell, daily or cumulative sequence under one time or speed schedule against a similar type of sequence under another schedule. By this method the working capacity even of different factories and of entirely different districts can be compared. The fact that the comparison is primarily one of consecutive periods under the same conditions of personnel, incentive and feasibility eliminates the main disturbing factors, yet differences in duration, distribution, speed and load of activity will all have their effect on working capacity manifested in the *shape* of the "curve".

A communication to the 14th International Congress of Hygiene and Demography by Dr. Emil Roth contains a comparison of the amount of electrical current used at the Siemens and Halske works before and after a change in or-

ganization. When the hours of work were 7:00-8:30, 9:00-12:00, 2:00-4:00 and 4:30-6:00, and the worker brought his own food, there was a slow increase in current at first, a maximum at 9:30-11:30, and a fast falling off and less current generally in the afternoon than morning. When the hours of work were 7:00-8:30, 9:00-12:00, 12:30-2:30, 3:00-4:30, and food was provided, there was a fast increase at first, a maximum at 9:15-11:45, little falling off, and current almost as high in the afternoon as in the morning. Dr. Roth is careful to point out, however, that a stricter discipline was enforced after the change that may explain some of the increase of current.

The contrast of sequences is of particular value where the effect of newly introduced recess periods is sought. While the hours before the recess should yield the same working capacity, the hours after the recess should show a change which can be expressed, without fear of ambiguity, *relatively* to the working capacity of the earlier, constant, hours.

PART V

THE DEMONSTRATION OF CONDITIONS PREDISPOSING TO FATIGUE

Correlation of Variations in Conditions of Industry with Associated Variations in Fatigue

On page 26 a schedule is given of all the factors in the present industrial situation which are likely to affect working capacity, particularly in predisposing or retarding the onset of fatigue. Their effect on working capacity is indirect; it is to *influence the influence* of length and intensity of activity.

In the case of a good many of these factors it is statistically possible to measure the exact force of their influence; and this further investigation is often of the greatest practical importance for two reasons:

(1) Some of these factors, by causing variations in working capacity, are liable to render the exact influence of length and intensity of activity somewhat ambiguous. The problem is much the same as that presented in the measurement of working capacity through the industrial data "in the foreground" (page 30). There it was a question how far output *etc.* was measuring working capacity unambiguously; here how far working capacity itself is affected by the length and intensity of activity unambiguously. The danger of ambiguity is due to the fact that while activity proceeds, time is also proceeding, and with the passing of time variations occur that affect working capacity, but which are not directly due to length or intensity of activity. The most

important of these variations contemporaneous with, but distinct from, activity occur in the natural periodicities of temperature and light and of certain physiological processes of the human body, and occur also in the fact of learning.

(2) Some of these "additional" factors must be scientifically studied before an answer can be given to the questions raised in Chapter IX. They are factors that can be changed in their force by action of employers, employees or the government: such as factory temperature, humidity and ventilation, generally; nutrition depending on the provision of canteens by the management, or the payment of sufficient wages; the selection of suitable workers for each kind of work; and, finally, the instruction of new hands in the most efficient methods.

The factors additional to length and intensity of activity that it is both possible and important to study may be grouped as follows:

1. The process of learning by experience. — Chapter XIII.
2. The factory conditions.—Chapter XIV.
   Atmosphere, nutrition and other natural conditions.
   The occurrence of activity at unusual times: nightwork, overtime, Sunday labor.
3. The type of worker.—Chapter XV.
   Differences of age, sex and race. Different habits.
4. The nature of the work.—Chapter XVI.

In each situation the investigator must consider: (1) the method of analyzing, measuring and determining the nature and the strength of the factor, (2) the method of associating the influence of that factor with the influence of activity upon working capacity, or of dissociating the two, if the factor is introducing ambiguities.

Some individual factors capable of being studied and important to study, specified in the schedule under the habits of the worker, might be grouped under different heads. Thus, nutrition may be a factory condition or else belong to the type of worker group, according to whether the management of the factory has extended its work to the provision of meals in canteens or whether the means for getting food is left to the initiative of the worker. In this latter case, however, the standard of nutrition is so closely bound up with the scale of wages paid by the factory that the whole question of nutrition is in fact still determined by factory policy. A study of budgets of working families has brought out the fact that the poorer the family the greater proportion of the whole income from wages is spent on food—this proportion often rising to 60 or 65 per cent.

The same considerations apply to housing conditions, which accounts for the next heaviest expenditure of earnings. Housing determines the facilities for sleep and recreation, and for all hygienic living outside of the factory. The same class of worker—as classified in the factory payroll—is likely to enjoy the same class or " standard " of living.

Four factors in our schedule, however, will differentiate individual workers from their wage-class: (1) if earnings must be shared among many dependents; (2) if work is done at home in addition to the work in the factory; (3) if the worker has a long and difficult transit from home to factory; (4) the spending of earnings in debilitating habits, such as the use of stimulants. These factors are best considered under the Type of Worker group. Though not separately treated, their influence on fatigue can be discovered by the same process of analysis, measurement and correlation applied throughout.

CHAPTER XIII

The Process of Learning

The skill or experience of the worker is the general level of his working capacity. This skill is acquired by "learning" or "training," a process only partly dependent on length and intensity of activity. Attention, observation and the power to initiate observations on the one hand, and the formation and building-up of muscles, habits, and generally a new working structure and equipment are the essentials; and these vary with the mere passing of time quite as much as with length and intensity of activity. It is a process of adaptation quite as much as one of pure "practice," and once "adapted," the working capacity will not be increased, through "learning," by further activity.

The importance of studying the effect of the learning process on working capacity lies in the need of *dissociating* this effect from the general effect of length and intensity of activity. It is useless to compare the record of output, power consumption, accidents, spoiled work, and even of absences of any given groups of workers when they are inexperienced, with their records when they become experienced.

The important question is, how soon do workers become fully experienced. When that point is established, the investigator must be careful if possible to eliminate all records referring to workers still at the learning stage, or at any rate to eliminate all records comparing individuals at different stages of the learning period. Just as in vital statistics, the age-constitution of the population must be the same

before death rates can be compared, so here *the experience-constitution of the groups compared must be equivalent on the whole.*

Some attempts have been made by the writer to measure the strength of the influence of training,—how greatly it increases working capacity and for how long the improvement may be traced. Weber has also attempted to trace certain fluctuations in the course of training.

The rate of accidents per 100 employed in several departments of a large American munition plant was compared for twelve consecutive months with the proportion (per 100 employed) of new hands hired each month by the same departments. The striking agreement in the fluctuations of the two curves showed clearly how low is the capacity to avoid accident due specifically to an experience of less than one month.

Studying the output of girls turning shells and parts of the fuse on capstan lathes, I found them still gaining in proficiency six months after starting on the work. The girls washing and drying shell-cases in the same department were, however, gaining much more slowly and seemed to have become trained.

From a study in a highly organized munition factory, of newcomers' "efficiency" compared with a standard production (expressed as 100) it appeared that an individual girl may materially improve at operations such as drilling and tapping small parts even in her twentieth week of experience. Her progress would seem to go in stages of three or four weeks. Thus, to take the average of twenty girls or more, their comparative efficiency began in the second week at 79 and rose to 87 in the third, but after that there was a fall till the seventh week (79 again), a rise up to the thirteenth week (97), a fall to the sixteenth (88), and a rise to the twentieth (102).

In the same factory another interesting case of improvement by learning was disclosed in studying the first week in which grenade-rod straighteners (hammering by hand) were put on nightshift. The total output of seven girls from Monday to Friday was as follows: 1290, 1420, 1577, 1605 and 1745.

Where the machine is semi-automatic, *e. g.*, where the operator instead of exercising his hands or controlling the starting, changing or stopping of the machine is merely feeding the machine with material as in the making of rifle cartridge-cases or bullets, learning is a much shorter process, and adaptation sooner achieved. At a munition factory near London the opinion of the foremen in the cartridge-case-making department was that two months should be sufficient for a girl to learn these simple processes, but further light was thrown on the subject by a statistical study the writer made in the bullet-making department. This department acquired its full complement of workers by May in a certain year and from that date the output rose steadily till the end of October, after which the rate of output remained stationary. A somewhat longer period than two months seemed to be required therefore for the workers to learn their job, though probably a large proportion of the six months' improvement was due to the gradually improving organization of this new department.

In the British Health of Munition Workers Committee's Interim Report (page 73) further tabular examples are given of the way the factor of learning increases working capacity. Here again it is reported that while in the work on semi-automatic machines most girls reached full proficiency in the sixth week, those "engaged at mouth-reamering, an operation involving more quickness and dexterity than the others, did not reach their full output till the eighth week. In certain shell operations, such as 'boring the powder

chamber' and 'finishing, turning and forming,' Dr. Vernon found that men took three or four months to attain their full output." The length of the learning process is seen, therefore, to depend largely on the nature of the work and the faculties required of the worker.

One queer exception to this rule, however, is instanced by Dr. Vernon. He reports that "the operatives engaged at turning fuze bodies nearly attained their full output in three weeks." [1] Yet turning fuze bodies involves subjecting each fuze body to seven successive boring and cutting operations.[2]

It is in the case of cumulative studies that the factor of learning is likely to cause the greatest ambiguity. Taking the cumulative study cited on page 125 of the girls making rifle cartridges, let us see how the disturbing factor of increasing "proficiency" or experience can be eliminated or excluded. It had been found that the individual output rate had increased in a period of four months about 4 per cent. To discover how far this increase was due to the large increases in the output rate which comparatively new girls would effect while learning their work, the girls in each group of processes were placed in classes according to the length of time they had been in the factory.

Comparing the changes in the output rate of these different classes of girls with the variation in the output rate for the girls as a whole, it will be seen from the table given below that the classes of girls that began the work at the earlier date usually have the highest rate in the earliest week recorded but that in the later recorded weeks this lead is lost. The girls that started before January show a definite tendency to be overtaken and the girls that started later seem to be catching up.

[1] *Report*, p. 73.

[2] *Ibid.*, p. 17.

	Number of girls	Output on week ending		
		Aug. 31	Sept. 21	Nov. 2 and 9
All classes	34	100	112	104
Class starting				
I Before January	6	100½	116	102
II Feb., March, or April	12	96½	106	100
III May or June	9	107½	116	114
IV Since June	7	94½	113	100

CHAPTER XIV

Factory Conditions

VENTILATION, PROVISION OF MEALS, NIGHTWORK AND OVERTIME

Analysis: 1. The effect on working capacity of ventilation conditions, so often made the subject of investigation, depends on several different elements, such as temperature, humidity, and the cooling and skin-stimulating properties of the air. The degree of temperature is measurable by the ordinary thermometer; the degree of temperature and humidity by the wet-bulb thermometer; while all three elements can now be measured by the Kata thermometer as used for the British Health of Munition Workers Committee.[1]

A large bulbed spirit thermometer (of standard size) is used; this is heated in hot water, and the rate of cooling measured by taking the time which the meniscus takes to drop from 100 degrees F. to 95 degrees F. while the instrument is suspended in the atmosphere. This gives the dry reading, and shows the rate of cooling due to radiation and convection. To take the wet reading the bulb of the Kata thermometer is covered with a damp muslin glove and the operation repeated, giving the rate of cooling when evaporation is added to radiation and convection. The rate of cooling at body temperature is recorded by means of a factor (determined for each Kata thermometer) in mille calories per square centimetre per second. The number

[1] *Memorandum*, no. 9, p. 4, note.

of seconds occupied in the fall from 100 degrees to 95 degrees is divided into the factor.

The nature and measure of nutrition may be analyzed as follows:[1]

Natural foods yield the essentials required to replace the energy expended and for the repair and growth of the body. They contain these essentials in the form of protein, fat, and carbohydrates, and also supply salts and certain substances of unknown nature, called vitamines, which exist in minute quantities in fresh foods and are necessary for the growth and health of the body.

The energy value of a foodstuff can be determined by burning a weighed quantity of it in a suitable apparatus called a calorimeter, and ascertaining how much heat it gives off. The large calorie, which is used as the unit of energy value, is the amount of heat required to raise 1 kilogramme (1¾ pints) of water through 1 degree Centigrade (1.8 degrees Fahrenheit). Calculation has shown that, when dried, foodstuffs contain the following energy value:

One gramme of—			
Protein	Contains	4.1	calories.
Carbohydrate	"	4.1	"
Fat	"	9.3	"

Many industrial situations that have formed the subject of special investigation are shown on analysis to consist of a complex combination of some of the individual factors set down in the schedule.

Thus, nightwork is studied as distinct from daywork not because activity is necessarily longer or more intense at night, but because certain special predisposing factors enter into consideration. The most important are: (1) The reversal of the workers' habits and its possible effect on the

[1] *Memorandum*, no. 11, pp. 3, 4.

physiological functions, especially where the same group of workers is constantly changing over or rotating from day to night shift and night to day shift. (2) The necessity of working in artificial light. (3) The difficulties of securing sleep under existing housing conditions.

When working overtime or on Sundays, again, the worker is not merely being paid at a higher rate of wage but usually he is in a quite different frame of mind than at ordinary times. On Sundays he will feel in holiday mood and is liable not to take his work very seriously, while when working overtime he often feels grim. If he is to stay at work he means to make the most by it.

Association: Factory conditions may be associated "directly" with total working capacity, as by Dr. Ellsworth Huntington, who compared the piece-earnings of the same two Connecticut factories under different weather conditions, particularly different levels of temperature and any sudden changes in temperature. But to show their influence on the causation of fatigue, natural conditions should be associated not directly with total working capacity but with the consecutive curve of capacity, its increase or decrease as influenced by activity. Thus, in the cold winter months the writer found a larger proportion of the day's accidents occurring in the first hours of work before the workers were "warmed up" by activity than occurred in the earlier hours of a summer's day.

Again the writer has noted the effect of food provided by the factory not "directly" by comparing records of workers' capacity with and without previous nourishment, but relatively by comparing the course or curve of working capacity when interrupted by a meal and when not so interrupted.

The stenographer (p. 111) typing letters from a dictaphone, for instance, was found to increase her output from

2 lines per minute in the morning and afternoon to 2.83 and 2.16 lines in the evening periods when no tea was taken, but from 2 lines to 3.83 and 2.83 in the same periods after tea had been taken.

The influence of activity on the working capacity at unusual times of work may also either be contrasted directly with that of the same workers performed in ordinary times or else consecutive studies on each occasion may be contrasted.

Many direct contrasts of day and night work are given in the Health of Munition Workers Committee's Report (pages 28-40), the output of any given group of workers on nightshift being expressed as a percentage of their output on dayshift. In making direct contrasts between nightwork and daywork the investigator is in most cases confronted with a dilemma. Where, as is usual, the shifts rotate, *i. e.* the workers on nightshift change over to dayshift and *vice versa* every week, fortnight or month, the influence of working at night may not show itself immediately in the working capacity while on nightshift; it may not find full expression till the first part of the period when the worker is on dayshift. On the other hand, if the night shift remains continuously at nightwork and dayshift continuously on daywork, though the results show clearly the effect of each time of work, yet the workers compared will not be the same set of individuals and any difference in the effect will be attributable to a different type of worker.

The study likely to be of the greatest importance and most free from ambiguity is to make a cumulative study of nightwork where shifts do not rotate. In this way the accumulated effects of work occurring continuously night after night will be observable.

Dissociation: Where the investigator wishes to study the effect on working capacity of activity pure and simple apart

from the variations of natural conditions, he must take into account the period over which his studies extend. Consecutive studies and comparisons by contrast will in this respect be subject to different considerations.

Comparisons by contrast where the period covered is not identical with any natural periodicity are only rendered ambiguous in so far as the time of year or day happened incidentally to be different in the different periods compared; but in consecutive studies of an industrial cycle, such as the working day, working capacity is regularly exposed to the disturbing influence of the natural periodicities or cycles. During the day the light and temperature outside the factory will increase and then decrease and between day and night the temperature of the human body also tends to vary in a regular sequence.

The temperature of the human body is not constant, but is known to exhibit a distinct cycle during the 24 hours, the maximum appearing between 4 p. m. and 8 p. m., and the minimum between 2 a. m. and 6 a. m. The difference, although the actual maxima and minima are not the same in different persons, may be said to be between 1 and 2 degrees (Fahrenheit). The natural explanation of this cycle is that it reflects the diurnal variations of bodily combustion, in particular that going on in the muscles.[1]

Cumulative studies over a period of a year or more, also, must take account of the fact that during the year there are the variations of the seasons in light and temperature—variations that may cause the greatest difference in the state of health of the human body. In measuring working capacity by means of the Proportion of Absences, for instance, it

[1] *Interim Report, British Health of Munition Workers Committee,* p. 27. See also Hollingworth, "Variations in Efficiency during the Working Day," *The Psychological Review,* vol. xxi, no. 6.

will be found that absences are almost invariably in greater proportion in the winter than at other times owing to the prevalence of rheumatism, influenza and colds.

Loveday gives the average monthly fluctuations in the percentage of members of an important trade union on sick benefit for the years 1910 to 1915. Relative variations for each month are given as reckoned from "the mean of the means of these years" = 10.

Jan.	11.7	July	8.9
Feb.	11.9	Aug.	8.9
Mar.	11.5	Sept.	9.1
April	10.6	Oct.	9.2
May	9.8	Nov.	9.7
June	9.2	Dec.	9.3

To dissociate variations in working capacity due to seasonal and climatic conditions from variations in capacity due to activity, tables such as the above for each separate district should be standardized and used to "correct" the variations in working capacity. Thus if working capacity is being compared in January and July by means of absence-ratios the January figure should be divided by 1.17 and the July figure by .89 so as to stabilize the disturbing influence of the season.

Three further factory conditions amenable to quantitive enumeration and to correlation with working capacity are light, smell, and noise. The former has been thoroughly analyzed (see for instance, Hollingworth and Poffenberger, "Applied Psychology" pp. 120-130) and its gradations can be measured by the photometer; but the latter two have been sadly neglected. Inventions to measure smell or noise would help to prove how true or false is the assurance that factory workers soon become "acclimatized."

CHAPTER XV

The Type of Worker

The effect of age and sex upon the influence of activity or working capacity acquires importance from the large number of young persons, *i. e.* from 14 to 18 years of age, that are still permitted to pursue industrial occupations in American and European factories, and also from the large influx of women into industry, particularly the munitions industry, to replace men required for military service. The effect of the factor of race is also extremely important in America, with its industrial population of negroes and immigrants.

Analysis.—The age of workers is obviously enumerable according to years, but the importance of distinguishing between different years lies first in the process of physical and mental growth taking place in the years up to 18 and the comparative weakness of young persons at any rate up to the sixteenth year. Below 13, children are only rarely found in industry. When growing, boys and girls need more sleep and rest to build up the tissues and more recreation to develop the character than do adult persons. A length and intensity of activity that will do adults no harm, may permanently stunt the rising generation.

The prime physiological differences between the sexes as they affect working capacity in industry are reducible to two. Women have less muscular strength, though possibly able to endure more nervously, and women are subject each month to a period of sickness. While there has been a great

deal of loose speculation on the subject, scientific study of the effect of these differences has been shamefully shirked. Yet this study is of the utmost importance in the assignment of work to women and in granting them periodical holidays as recommended by Frederick Taylor.[1]

The differences between sexes that are important in industry are not purely physiological; there are what may be called secondary circumstances or accompaniments, that, possibly, have far greater influence on working capacity. Women, for instance, often have housework to perform in the home in addition to their work in the factory. They wear more inconvenient clothes than men, and they are more restricted by convention in the rest they can obtain by a relaxed posture.

Races seem to differ greatly in nervous energy and excitability. It is doubtful, for instance, whether the negro could fulfil the conditions required for nervous work at high tension, but he is possibly peculiarly adapted to uniform routine operations.

Association. — Many investigations into the effects of activity have brought out, usually quite incidentally, the important influence of different sexes and ages in retarding or predisposing the onset of fatigue. The influence of race has hitherto been somewhat neglected, but investigations can proceed along the same lines as with sex and age.

Dr. Vernon, using what may be called the double contrast method, finds that a reduction of hours for boys increases their working capacity more than a roughly corresponding reduction of hours in roughly similar work increases the working capacity of adult men. His results may be abridged and focussed as follows:

[1] *Principles of Scientific Management*, p. 96.

	Average Hours of actual work	*Reduction (Relative)*	*Average Hourly output (Relative)*
9 Youths Age 15–18, Sizing Base Plugs....	68.3		100
	60.9	11%	155
27 Men Sizing Fuze Bodies.....	61.5		100
	55.4	10%	122

In the 1915 Report to the British Association the writer contrasted the hourly sequence of women's and of men's accidents throughout the day in the Lancashire cotton industry and found that while accidents to women rose persistently throughout each spell, accidents to men dropped slightly in both spells about an hour before the interval. Tentatively, the difference was attributed to the fact that while men might brighten up in anticipation of rest and food, to women the interval often meant only household drudgery.

As for "Habits," only a few have enumerable variations enough to be correlated. Transit and home duties can be measured by the time spent; support of dependents, and possibly use of stimulants by the proportion of earnings expended. As for the workers' "Point of View," psychologists seem to find only "General Intelligence" really measurable by their tests.

CHAPTER XVI

The Nature of the Work

Analysis: The first step towards gauging the force of the nature of the work in "influencing the influence" of activity on working capacity is to be able to analyze and measure what is the intensity of activity involved in each kind of work. In Chapter XI we studied the relative intensity of activity due to varieties of speeding and loading. Here we have to deal with differences in intensity due to the different physical and mental requirements of various kinds of work; the kind of call that the work makes upon the human organism. The actual operations of industry taken as a whole are not measurable in common terms: they cannot be graded quantitatively in terms of intensity of activity. Yet if we analyze operations from the standpoint of the call they make, certain simple types will be found, composed of elements that can be graded quantitatively. Lifting pigiron on to a truck, for instance, consists almost entirely of a call on the muscles of the back and limbs. This call on the muscles is determined primarily by the *weight* of the material that is moved, lifted or sustained, by the *distance* and direction through which it is moved and by the *time* during which the worker is under load, all quantitatively measurable.

The reports to the British Health of Munition Workers Committee when dealing with the nature of the work confine themselves to a very rough classification of work into grades of "heaviness". Dr. Vernon, in Memorandum 12, suggests five such types: very heavy, heavy, moderately heavy, light, and very light, as being a convenient division, while Dr. Agnew (Report, page 87) bases a fourfold grad-

ing partly upon the weight of work, partly upon the conditions of heat, noise, *etc.*

This division is hardly very "objective"; the definitions depend not on independent measurement but partly on the mere opinion of the investigator, partly on the results obtained *after* investigation, which flagrantly begs the question. Nor is the comparative intensity of different kinds of operation quite so simple a matter as the mere heaviness of the work. The intensity of even the purely muscular call will vary according to the weakness of the muscles employed, and when we proceed to study what psychological or nervous faculties are called into play, investigation must proceed still deeper.

For this purpose the investigator should use a table or blank form similar to that used for motion study, but more complicated. A sketch is given on the next page, filled in roughly with a sample operation from the textile industry. By means of this table part of the field of industry can be analyzed into definite types of work within which grades may more easily be *measurable*. Occupations will be distinguished according (a) to the nature of the elementary motions, (b) according to the relation of the motions within the operation, and (c) according to the relation existing between the separate operations.

A. The elementary motions or attitudes, "agencies" and postures are to be noted in the top space of the columns, (1), (2), (3), *etc.*, and the time spent noted in the space below. The investigator should record in the middle what tax or "call" is made upon the neuromuscular system; whether the task performed by each motion consists in the moving or sustaining of heavy weights requiring strength, or in concentrated, delicate or finicky manipulation requiring dexterity. He should also look out for attitudes involving attention and judgment and requiring considerable nervous tension.

Name of Operation: *Cotton Spinning; "Piecing-up"*

Object of Operation: *To preserve the continuity of the thread*

Tools or Machines: *Six Ring-Frames*

Materials used:

	REITERATED TASKS					OCCASIONAL TASKS			
	1	Cue	2	Cue	3	Cue	i	Cue	ii
Motions or Attitudes and agency used	Attending for break in thread	Break noticed by eye	Stopping the frame Piecing up with fingers	Motion (2) completed satisfactorily	Restarting frame with right hand	Spindles full	Removing old spindles	Motion i completed	Replacing new spindles
"Call" involved	Strained Attention	Acute Vision	Dexterity	Judgment	Rapidity		Muscular Strength		
Posture	Standing up		Stooping			Standing			
Time Spent (1) Average									
(2) Mean Deviation									

B. How the motions fit into the whole operation depends mainly on their time-relation, whether they are simultaneous or consecutive. If simultaneous the motions should be noted down in the table under the same column; if consecutive, the "cue" must be stated which starts off each motion, whether it be the completion of the previous motion or some sign outside the operation. For this purpose a column is provided between each main motion column. If the motions are simultaneous or overlap, or the cues for the consecutive motions come from outside, an operation may be said to be *complex*.

Any pauses that occur between motions in the course of the operation and the time spent should be noted down a column as though it were a single motion. A worker may be said to be "pausing" when he is not engaged in actually performing some particular function and is simply waiting for the completion of some material process, (as when machine tools are actually in contact with the material) or waiting for fellow-workers to finish some particular job. The "performance of function" includes attending for cues of all kinds, and pauses will thus consist only of periods where the worker can completely relax. Operations including many pauses may be called "*intermittent*".

C. The relation between the distinct operations is more easily ascertained. Once any operation is found uniformly repeated (*i. e.* where the motions within each recurrent operation are absolutely similar) then the questions arise, (1) how *frequently* each similar operation is repeated on the average, and (2) how *regularly* each similar operation is repeated—what the mean *deviation* in duration of time of individual *repetitions* is *from the average* time of all operations.

This method of dividing up industrial operations will yield the following seven elementary types of work: mus-

cular, dexterous, nervous, complex, intermittent, frequent, and irregular. It should be noted that actual operations found in industry may be composed of two or more elements. Piecing-up, for instance, is dexterous, nerve-racking, and irregularly repeated.

Below are scheduled the seven elementary types of work under the threefold basis of differentiation. Where possible, particulars are subjoined of the methods of measuring these elements of strain and of the feelings evoked in the worker, and examples are given of actual industrial operations where the elements can be found *in situ.*

A. *The Nature of the Elementary Motions or Attitudes.*

1. Muscular Strain.

Measure (partly): Comparison of the work involved to that of raising given weights to a given height perpendicularly.

Examples: Steel-making; gun and large shell forging; smithy work where hammers of 18 lbs. weight are used; wheeling quantities of metal, bricklaying and ordinary laboring; sizing fuze bodies which requires great and continuous strain on the muscles of one arm and shoulder and to a less extent on those of the back. The upright posture always involves a strain on the central muscular system.

2. Dexterous Manipulation.

Measure: Degree of concentration of the muscular field employed, *e. g.* the tips of the fingers only.

Examples: Tying or wrapping up packets; assembling and machining very small parts—where the material has to be placed and guided exactly, on a tool continuously in operation.

3. Nervous Tension.

Examples: Soldering, mending, inspecting and gauging, and most skilled trades exercise a judgment of "quality" in the sense of a comparison with a standard kept in memory. Pasting on labels or cutting articles accurately to shape involves not merely "sensitivity" of the eyes, but the "judgment of distance" and a co-ordination of muscles; and inserting articles in revolving slots like the paper in a rotary litho machine involves a "judgment of time." There is also, perhaps, a "sense or judgment of amounts" which is involved where, as in the "stogey" industry, emphasis is placed on close cutting, and to avoid wasting an unnecessary amount of leaf the rate of pay is more, the more cigars are made from a given amount of the raw material. Piecing-up the threads of cotton in spinning, and all machine-minding and watching, whether it be the work of the machine or the machine itself that requires attendance, involves the attitude of attention, or rather expectancy for a "cue" irregular and difficult to perceive, and a quick reaction to the cue when it occurs. At no time is relaxation assured. The same effect is produced where the danger of accident is continually present, as where the fingers move in close contact with machinery or where sparks are flying about.

B. *The Relation of Motions within Operation.*

4. The Complex Operation.

Measure: Several motions occurring simultaneously or overlapping, or where motions have to follow on a special "cue".

Evokes feeling of worry and requires co-ordination of muscles.

Examples: Wherever the machine or engine is controlled or driven by the worker, especially if the material has to be guided through in addition.

In the internal transportation of a factory, pulling levers and handles to move cranes and hoists exactly at the right moment and exactly to the right place.

5. The Intermittent Operation.

Measure: Where pauses occur (see page 24) in the midst of the operation.

Examples: Wherever material has to "set" or undergo other technical processes without human interference.

E. g.: Iron and steel works where stop-watch observations have shown pauses to take up from 28 to 60 per cent of total working time.

C. *Relation between Uniformly Repeated Operations.*

6. Frequently Repeated Operations.

Frequency *measurable* by average amount of product per man per day.

Evokes feelings of monotony and boredom and a sense of being driven, but may lead to rhythm.

Examples: Wherever there is extreme subdivision of labor with the use of semi-automatic machinery, where the worker only feeds or empties the machine; and where the material itself is standardized.

E. g.: Rifle cartridge-making. Each worker often turns out from 4,000 to 7, 000 products per hour.

7. Irregularly Repeated Operations.

Irregularity *measurable* by mean deviation of intervals between operations from the average interval.

Evoke flurry and irritability.

Examples: The repairing of machines, telephone operation, and all dealings with people.

Association: It is obvious from the discussion of ambiguities in measuring working capacity that the rate of accidents, spoiled work, consumption of power and especially of output cannot be contrasted directly as between different types of work; the only chance of a clear issue lies either in what may be called the double contrast or in contrasting the sequences or time-distributions in the different types.

A good example of the double contrast is given by Abbé. At the same time that he contrasted the piece-earnings at the Zeiss Optical Works in the nine and the eight-hour day he also contrasted the contrast in the output per hour for the whole factory with the contrast in the output of the different operations. He found that the output from carpenters increased 20.3 per cent, from engravers by hand 19.3 per cent, while that from microscope grinders only increased 9.4 per cent, and so on. The net effect of different types of work can thus be shown in a so-called table of double entry.

PIECE EARNINGS PER HOUR

Operation	*in 9 Hour Day*	*in 8 Hour Day*
Carpentering	100	120.3
Engraving	100	119.3
Grinding	100	109.4
Whole Factory	100	116.7

As to the contrast of sequences, an attempt was made by the present writer in the 1915 Report of the Committee of

the British Association to examine how far differences in the output and accident time distributions are attributable to differences in the factor, " Nature of the Work."

Extremely interesting differences were found, particularly in the hourly sequence of the output measure. The frequently repeated type of operation and the intermittent type of operations showed no decrease at the end of a spell, contrary to the output curve for the type involving muscular strain and nervous tension. Again, the type with motions involving dexterous manipulation showed a heavy fall in output toward the end of a spell but a quick rise in output after taking any rest, while work involving a larger muscle area showed less susceptibility to *immediate* fatigue and *immediate* recovery.

These results are cited merely to suggest the importance of associating differently analyzed types of work, with the influence of length and intensity of activity. The nature of the work seems, if current research is to be trusted, to have by far the greatest influence of any predisposing condition.

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